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ENTHESEAL CHANGES AND BONE GEOMETRY AS IDENTIFICATION TRAITS IN FORENSIC ANTHROPOLOGY:

BUILDING AN INTERPRETATION GUIDE.

Tese de doutoramento em Antropologia - Ramo de Especialização em Antropologia Forense, orientada pela Professora Doutora Eugénia Cunha e pela Doutora Charlotte Yvette Henderson e apresentada ao Departamento de Ciências da Vida da Faculdade de Ciências e Tecnologia da Universidade de Coimbra

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Faculdade de Ciências e Tecnologia
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Entheseal changes and bone geometry as identification traits in forensic anthropology:

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List of Abbreviations

AAAS: American Association for the Advancement of Sciences.

AUC: Autodefensas Unidas de Colombia – United Self-Defense Forces of Colombia.

BF(Z1): Bone formation in zone 1.

BF(Z2): Bone formation in zone 2.

BMI: Body mass index.

CA: Cavitation.

CEO: Common extensor origin.

CFO: Common flexor origin.

CH: Charlotte Henderson.

CNMH: Centro Nacional de Memoria Histórica – National Center of Historical Memory.

DNA: Deoxyribonucleic acid.

DISH: Diffuse idiopathic skeletal hyperostosis.

DSP: Diagnose sexuelle probabiliste – Probabilistic sex diagnosis.

EAAF: Equipo Argentino de Antropología Forense – Argentine Forensic Anthropology Team.

EB: Edgar Bernal.

EC: Entheseal change.

ECs: Entheseal changes.

EDB: External dimensions of bone diaphysis.

ER(Z1): Erosion in zone 1.

ER(Z2): Erosion in zone 2.

FA: Forensic anthropology.

FARC: Fuerzas Armadas Revolucionarias de Colombia – Revolutionary Armed Forces of Colombia.

FB: Fibrous.

FBI: Federal Bureau of Investigation.

FC: Fibrocartilaginous.

FPO: Fine porosity.

GLM: Generalized linear model.

ICRC: International Committee of the Red Cross.

INMLCF: Instituto Nacional de Medicina Legal y Ciencias Forenses – National Institute of Legal Medicine and Forensic Sciences.
JPL: Justice and Peace Law – Ley de Justicia y Paz.
MA: Maria Acosta.
MO: Myositis ossificans.
MOC: Myositis ossificans circumscripta.
MOP: Myositis ossificans progressiva.
MPO: Macro-porosity.
SD: Standard deviation.
SpA: Spondyloarthropathies.
SWGANTH: Scientific Working Group for Forensic Anthropology.
PsA: Psoriatic arthritis.
UdeA: Universidad de Antioquia – University of Antioquia.

XXIUC: XXI Century Skeletal Collection, University of Coimbra.

Abstract

This research aims to improve the contribution of forensic anthropology to the personal identification process by analyzing the relationship between entheseal changes and skeletal evidence of antemortem trauma in Colombian male individuals. The analysis of the research is separated into two areas: to identify the prevalence of entheseal changes (ECs) in identified male Colombian individuals, and to recognize the effect of antemortem trauma on entheseal changes in the population of forensic interest in Colombia.

Forensic anthropology has made important contributions to the personal identification process, particularly in complex cases such as mass disasters, armed conflicts, crimes against humanity, and migration crises where antemortem records are non-existent or insufficient to apply traditional methods of identification, such as Colombia. Nowadays, Colombia has a total of 34,743 unidentified deceased individuals, a number that continues to grow. Of these, 53.8% are young adult males. Given the extent of the internal armed conflict and the drug trafficking violence, most of these cases are fully skeletonized bodies. Furthermore, the multifactorial etiology of EC has limited their use in forensic cases, but the effect of trauma on EC are worth exploring in the effort to prove antemortem injuries that may be reported by relatives, particularly those affecting muscle tissue.

All macroscopic skeletal evidence of traumatic injuries were recorded as antemortem trauma. The sample was comprised of 171 male individuals between the ages of 20 and 68 from two identified skeletal collections in Colombia: The University of Antioquia's (UdeA) collection, and the National Institute of Legal Medicine and Forensic Science's (NILMFS) collection. Any alteration of the normal entheseal surface of fourteen fibrocartilaginous entheses was recorded according to the scoring system of the new Coimbra method.

The research found more presence of ECs in the NILMFS than in the UdeA collection. However, trends changed and became stronger when age was taken into consideration: young and middle adults from the UdeA collection had more ECs. This research also demonstrates that antemortem trauma is related to textural change, fine porosity, and erosions in entheses near the lesion site and other segments of the same limb or the opposite limb. However, this relationship is not straightforward and other factors such as health status, age, and the individual’s physiological limits or load capacity may play relevant roles in the strength of this relationship.

The research results highlight the potential usefulness of ECs as additional evidence of antemortem trauma when body segments are missing, or the bone evidence is not sufficiently clear. The results also show that despite belonging to the same country, the population variability of each region is a factor that must be considered when assessing morphological features such as ECs. In conclusion, ECs are associated with skeletal evidence of antemortem trauma and are potential individualizing characteristics if other factors such as age and population variability are taken into consideration.

Keywords: myositis ossificans, fractures, compensatory movements, injuries, personal identification, Colombia.

Resumo

Esta pesquisa tem como objetivo melhorar a contribuição da antropologia forense para o processo de identificação pessoal, analisando a relação entre alterações das enteses e evidências esqueléticas de trauma antes da morte em indivíduos colombianos do sexo masculino. A análise foi dividida em duas partes: identificar a prevalência de alterações das enteses (ECs, por sua sigla em inglês) em indivíduos colombianos do sexo masculino e reconhecer o efeito do traumatismo antemortem nas ECs na população de interesse forense na Colômbia.

A antropologia forense tem feito contribuições importantes para o processo de identificação pessoal, particularmente em casos complexos, como desastres em massa, conflitos armados, crimes contra a humanidade e crises de migração onde os registros antemortem são inexistentes ou insuficientes para aplicar métodos tradicionais de identificação, como no caso da Colômbia. Atualmente, a Colômbia tem um total de 34.743 pessoas falecidas não identificadas, um número que não para de crescer. 53,8% dos indivíduos não identificados são adultos jovens do sexo masculino. Dada a extensão do conflito armado interno e da violência do tráfico de drogas, a maioria desses casos são corpos totalmente esqueletizados. Além disso, a etiologia multifatorial do EC limitou o seu uso em casos forenses, mas vale a pena explorar o efeito do trauma nas ECs de modo a comprovar lesões antemortem que podem ser relatadas por parentes próximos, particularmente aquelas que afetam o tecido muscular.

Todas as evidências macroscópicas do esqueleto de lesões traumáticas foram registradas como trauma antemortem. A amostra foi composta por 171 indivíduos do sexo masculino com idades entre 20 e 68 anos de duas coleções de esqueletos identificados da Colômbia: a coleção da Universidade de Antioquia (UdeA) e a coleção do Instituto Nacional de Medicina Legal e Ciência Forense (NILMFS). Qualquer alteração da superfície de catorze enteses fibrocartilaginosas foi registada de acordo com o sistema de pontuação do novo método de Coimbra.

Nesta investigação foram detetadas mais ECs na coleção do NILMFS do que na coleção UdeA. No entanto, as tendências mudaram e tornaram-se mais fortes quando a idade foi levada em consideração: os jovens e adultos de meia idade da coleção UdeA tinham mais ECs. Esta pesquisa também demonstra que o trauma antemortem está relacionado com a mudança textural, porosidade fina e erosões em enteses próximas ao local da lesão e outros segmentos do mesmo membro ou do oposto. No entanto, esta relação não é direta e outros fatores, como estado de saúde, idade e os limites fisiológicos ou capacidade de carga de cada indivíduo podem desempenhar papéis relevantes na força desta relação.

Os resultados desta investigação destacam a utilidade potencial das ECs como evidência adicional de traumatismo antes da morte sobretudo quando alguns segmentos corporais estão ausentes, ou quando a evidência óssea não é suficientemente clara. Os resultados também mostram que apesar de pertencer a um mesmo país a variabilidade populacional de cada região é um fator que deve ser considerado na avaliação de características morfológicas, como ECs. Em conclusão, as ECs estão associadas com as evidências ósseas de traumatismos antes da morte, e podem ser potenciais características individualizantes se outros fatores, como a idade e a variabilidade populacional, forem tidas em consideração.

Palavras chave: miosite ossificante, fraturas, movimentos compensatórios, lesões, identificação pessoal, Colômbia.

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There is a proverb saying that “it takes a village to raise a child”, I would say that it also takes a village to accomplish a Ph.D. thesis. It all begins with the seed, the idea of becoming a doctor, which was well planted by my parents Pia y Alejandro. They both showed me with their jobs as professionals and parents that does not matter what the plan is, it must be fully accomplished and enjoyed. Besides the purpose of having a doctorate, they gave me all the tools and resources needed for the journey. My brother contributed with his way of life. Juan had an active life that made me reflect on the human body and its scope and capabilities.

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INTRODUCTION

Forensic anthropology is a well-established science that aims to recover and analyze human remains of medico-legal interest (Ubelaker, 2018a). Personal identification remains a major challenge of forensic anthropology (Cunha & Cattaneo, 2018). Likewise, the information recorded in the human skeleton has assisted in the understanding of cause and manner of death, (Berryman et al., 2018; Symes et al., 2012), the analysis of a traumatic mechanism and pattern (Cattaneo et al., 2017; Davide Ferrara, 2017), age estimation and identification in the living (Black et al., 2010; Obertová et al., 2019).

Researchers from various countries have focused on creating, improving, and strengthening methods to increase accuracy in the four major elements of the biological profile and factors of personal identification using skeletal evidence (Cappella et al., 2019; Christensen, 2005b; Christensen et al., 2017; Cunha & Ubelaker, 2020; Djurić, 2004; Klales et al., 2012; Kotěrová et al., 2018; Langley et al., 2018; Michopoulou, Negre, et al., 2017; Monsalve & Hefner, 2016; Navega et al., 2015; Rivera-Sandoval et al., 2018; Steadman et al., 2006; Ubelaker, 2014; Yoshino et al., 1987). These improvements could be highly advantageous in contexts with numerous unsolved cases and/or where use of traditional methods of personal identification is limited (de Boer et al., 2020), such as Colombia.

Colombia has an ongoing internal conflict that has resulted in over 260,000 deaths (Centro Nacional de Memoria Histórica, 2012), of which at least 30,000 fully skeletonized individuals remain unidentified (INMLCF, 2021), and 83,000 cases of forced disappearance have been documented (Centro Nacional de Memoria Histórica, 2020). Of those skeletons, 79% belong to male individuals, most under 50 years old. Similarly, males constitute over 76% of the disappeared individuals (INMLCF, 2021).

The Colombian forensic context presents numerous challenges including cases from different time periods that are associated to multiple events, and with victims who were raised in different geographical regions of the country with diverse biological backgrounds, as well as social and family networks that are difficult to trace (further explained in Chapter 4) (López, 2020). Likewise, blood relatives with similar biological profiles may be found in the same forensic context (Reinoso, 2019; Rodríguez & Arango, 2014). This difficult forensic context requires interdisciplinary teamwork that limits the universe of victims thereby preventing false positive identifications or inconclusive results (López, 2020). For instance, in 2012 it was reported that 73% of the cases with presumptive identification were confirmed by DNA profiles, demonstrating the importance of the forensic anthropologist and other forensic practitioners in the identification process. However, this percentage only represented 13% of the cases under investigation during the same year (Arango-Rodríguez & Camargo, 2015). Skeletal identifiers could be a potential approach to improve presumptive identifications, and therefore increase positive identifications in Colombia.

It is necessary to rely on several accurate methods of personal identification, that particularly highlight the skeletal differences between young male individuals within the Colombian population, in order to strengthen the work of forensic anthropologists (Sanabria Medina & Osorio Restrepo, 2015). Therefore, this thesis aims to strengthen the methodology of forensic anthropology by analyzing the relationship between entheseal changes and antemortem trauma, and the usefulness of this relationship within the personal identification process in Colombian male individuals.

Anthropological identifiers include external morphological such as face, teeth, scars, and moles (that will not be addressed in this research), and skeletal features. Some of the skeletal features are anatomical variants, developmental abnormalities, pathological changes, medical interventions, frontal sinus and trabecular bone patterns (de Boer et al., 2020). Pathological changes associated with traumatic injuries, mostly fractures, are amongst the most frequent factors supporting personal identification (Djurić, 2004; Komar & Lathrop, 2006; Ríos et al., 2012; Silva et al., 2014), but most of the injuries are concentrated in the soft-tissue (Aitken et al., 2012; Lambers et al., 2012) and leave unclear and limited evidence on the skeleton. In those cases, is imperative to perform differential diagnose. Antemortem trauma that only affects soft tissue is currently outside of the forensic anthropological scope. However, it may be possible to utilize the muscle/bone interface (entheses) to identify soft tissue injuries, particularly muscle injuries.

An entheseal change (EC) is any alteration of the normal surface of the point where ligaments, muscles, and tendons attach to bone (Henderson et al., 2013; Villotte & Knüsel, 2013). The analysis of entheseal changes was first explored at the end of the 19th Century (Kennedy, 1989), and has developed in the last 30 years, with the predominant interest being inferring activity patterns in past societies based on the concept that frequent muscle activity changes the enthesis (Churchill & Morris, 1998; Dutour, 1986; V. Eshed et al., 2004; Havelková et al., 2011; Hawkey & Merbs, 1995; Kelley & Angel, 1987; Palmer et al., 2016; Schrader & Buzon, 2017; Villotte, Castex, et al., 2010; Villotte, Churchill, et al., 2010). During the 1990's, the idea of a multifactorial etiology of ECs began to solidify (Cunha & Umbelino, 1995; Wilczak, 1998), and yet reconstructions of behavior based on such skeletal markers continued to be conducted (Santos et al., 2011; Villotte & Knüsel, 2013).

In the early practice of forensic anthropology, it was common to assess individualization features, such as handedness and occupations, based on skeletal markers that were associated with frequent muscle activity like, but not restricted to, ECs, asymmetrical bones, and certain type of anatomical variants (Angel & Caldwell, 1984; Grisbaum & Ubelaker, 2001; Kennedy, 1989). For example, Lawrence Angel was interested in skeletal variations related to activity patterns (Angel, 1946, 1966; Kelley & Angel, 1987) and used his osteological training to infer physical activities in forensic cases (Prevedorou & Buikstra, 2014). Angel and Caldwell studied a forensic case in which they observed bony extensions in the mandible of a young woman (Angel & Caldwell, 1984). These skeletal changes prompted them to hypothesize that the victim used her jaw in a daily activity, such as playing a wind instrument. When the victim was identified, her relatives confirmed that she was a clarinet player from a young age (Byers, 2016).

Nowadays, skeletal evidence such as robust muscle markers are considered indicators of a physically active individuals (Cunha & Cattaneo, 2018; Ubelaker & Zarenko, 2012). However, forensic evidence must provide reliable information and the multifactorial etiology of ECs (Benjamin et al., 2006; Henderson & Alves Cardoso, 2013; Jurmain et al., 2012) limits their usefulness of these skeletal traits. Therefore, statements regarding specific occupations based on changes of the entheseal surface are no longer admitted in forensic reports as primary evidence. Justly, ECs were left outside of forensic anthropological research. In recent years, the analysis of ECs have been included to help estimate age-at-death in older individuals (Listi, 2016), and for calculation of the body mass index (BMI) (Godde et al., 2018; Godde & Taylor, 2013). These studies found that ECs are associated with aging and BMI, respectively, but the associations varied between entheses and none of the results were strong enough to predict age-at-death or BMI. However, their analysis pooled fibrous and fibrocartilaginous entheses together and scored ECs following either Hawkey and Merbs's (1995) method or Mariotti and colleagues' (2007) method (see discussion in Chapter 2). Both methods score the entheseal surface as a whole and do not assess each type of change, independently, therefore, it is difficult to refine the analyzes and identify the relationship between the factors involved and the different changes that can be observed on the entheseal surface.

It has been proposed that trauma can stimulate some types of EC (Jurmain, 2013b; Jurmain et al., 2012; Resnick & Niwayama, 1983; Schlecht, 2012), but none of the available literature has identified or systematically explored the effect of one-off trauma on EC. Skeletal markers related to one-off trauma were outside of the researchers' frame of reference as the original assumption for EC presence was that alterations of normal morphology of the entheses were linked to repeated activity. Fatigue or stress fractures were occasionally included in studies aiming to reconstruct behavior in past societies (Jurmain, 2013b; Merbs, 1996b, 1996a; Ortner & Putschar, 1985; Schrader & Buzon, 2017). However, antemortem trauma was never analyzed together with the presence of EC, except for the Schrader and Buzon study (2017), which uses both types of skeletal evidence as indicators of levels of activity of the individuals during everyday life in postcolonial Nubian. However, their study included only the traumatic injuries that could be related to accidental or occupational causes and did not explore the relationship between ECs and antemortem trauma.

Currently, soft tissue injuries are virtually impossible to track on the skeleton when no bone tissue has been directly affected i.e., bone fractures or secondary osteoarthritis associated with dislocations. Therefore, the analysis of the effect of trauma, particularly muscle injuries, on EC is forensically and osteologically relevant.

Objectives

The primary objective of this research is to improve the contribution of forensic anthropology to the personal identification process by analyzing the relationship between entheseal changes and skeletal evidence of antemortem trauma and the usefulness of this relationship within the personal identification process in Colombian male individuals.

The following two secondary objectives were set to reach the primary objective.

Objective 1

To determine the prevalence of EC in male individuals from two modern identified skeletal collections in Colombia. Population variability affects some biological factors that can be seen in the skeleton, such as height and nonmetric traits, and may affect the presence of some ECs. The description of the EC trends in male individuals of the Colombian population establishes a biological base from which other factors, such as trauma, can be further analyzed. Additionally, it can be determined whether there is population variability in the presence of EC between the two skeletal collections that are composed of individuals buried in two different regions of Colombia. Modern Colombian EC trends allow for future comparison with other modern skeletal collections in Colombia, as well as prevalence of EC in other skeletal collections around the globe.

Objective 2

To determine the association of EC and skeletal evidence of antemortem trauma in Colombian male individuals, if any. Traumatic injuries affect the human body in multiple aspects, from the impact itself to the recovery process. Entheses are the interface between muscles and bones, so they could be equally affected. Depending on whether this relationship exists and how strong it is, it strengthens the anthropological identifiers.

1. FORENSIC ANTHROPOLOGY AND ENTHESEAL CHANGES

1. LITERATURE REVIEW

The literature review focuses on four main topics that are relevant to the research question: the status of identification and scientific testimony in forensic anthropology (FA); the role of FA in the Colombian context; a summary of antemortem injuries and their skeletal evidence, the anatomy of entheses, and the current understanding of the etiology of the entheseal changes.

1.1. Forensic anthropology

1.1.1. Development of forensic anthropology

Forensic anthropology is a field of study that applies methodologies and knowledge of the separate fields of study of forensics, biomechanics, osteology, and anthropology to support medico-legal cases (Ubelaker, 2018b). It has evolved as a scientific discipline over the 20th century, but its contributions to court cases have been relevant since the 19th century when the identification of fragments of human bone was strong evidence to support Webster´s conviction for the murder of George Parkman (1849-1850) (Ubelaker, 2018a). Forensic anthropologists are trained in human anatomy and osteology enabling them to perform several tasks as follows (Cunha & Cattaneo, 2006):

- To aid in the recovery of human bones.
- To evaluate the postmortem interval.
- To reconstruct craniofacial features.
- To identify human from non-human bones.
- To assess biological profile.
- To recognize abnormal features and anatomical variants that may lead to individual identification.
- To contribute to personal identification of victims of natural and mass disasters.
- To investigate crimes against humanity.
- To identify and estimate age in the living.
- To assist forensic pathologists in the analysis of manner and cause of death.

Age estimation and identification in the living has become a relevant contribution of forensic anthropology to cases associated with refugee and migration crises around the globe, and child pornography. This last approach has been developed mainly in the European countries (Black et al., 2010; Cunha & Cattaneo, 2006; Obertová et al., 2019).

Positive identification has been the main goal of forensic anthropologists since their first contributions to Medico-Legal cases. Although the improvement and expansion of DNA testing was thought to undermine the contribution of forensic anthropology to personal identification (Dirkmaat & Cabo, 2012), the large number of unidentified human remains derived mainly from refugee and migration crises, internal conflicts, and natural disasters highlight that anthropological expertise is essential within forensic teams. Such contribution not only reduces the universe of possible identities through the assessment of the biological profile, but also provides solid skeletal identifiers in cases where the traditional means of identification cannot be used (de Boer et al., 2020; Díaz & Urueña, 2020; López, 2020).

The first contributions of FA to the forensic sciences were during the 19th century when Jeffries Wyman (1849-1850) and George Dorsey (1897-1898) analyzed skeletal evidence related to the murder cases of George Parkman (1849) and Louisa Luetgert (1897). Results of both cases brought attention to the fact that bones, or fragments of bone, could become solid evidence in medico-legal cases. At the end of the 19th century, Thomas Dwight became the first professor of anatomy to focus his research on the development of methodologies for systematic analyses of the human skeleton. He established the scientific foundation of forensic anthropology and is considered the “father of American forensic anthropology” (Ubelaker, 2018a). Over the course of the 20th Century, the FBI and the Smithsonian Institute built up a forensic relationship in which four different anthropologists, Alês Hrdlička, Thomas Stewart, Lawrence Angel, and Douglas Ubelaker, were consulted when human bones were under investigation (Ubelaker, 2018a). The publication of Wilton Krogman’s “A Guide to the Identification of Human Skeletal Material,” (1939) began to regulate the practice of physical anthropology within the forensic context. In the following decades, several new methods and techniques to assess biological profile were developed, along with basic guides to standardize the practice (Buikstra & Ubelaker, 1994; Krogman, 1939; Stewart, 1979; Trotter & Gleser, 1958). Since the 1990s, and due to the *Daubert* criteria (further explained below), protocols and techniques used by forensic anthropologists adhere more strictly to scientific methodology and practitioners are more aware of limitations and margin of error of each method (Christensen & Crowder, 2009).

The development of FA around the globe is closely linked to the development of the practice within the forensic sciences in the United States and academic research in both Europe and the United States (Ubelaker, 2018a). The progressive inclusion of forensic anthropologists in the assessment of both skeletal remains and age estimation of the living, and the growing options of specialized training that have been opening in different countries in the last 20 years, demonstrate that the practice of forensic anthropology in Europe is evolving (Obertová et al., 2019).

The development of forensic anthropology in South America was shaped by the forced disappearance and death of thousands of victims of the dictatorships, as well as protracted armed conflicts during the 1980’s and 1990’s, in which the respective national governments were responsible by act or omission. Until the early 1980s, despite the high rates of violent deaths and criminal cases in which forensic anthropology would have been a useful tool, the analysis of human bones was not relied upon in the judicial processes (Rodríguez Cuenca, 2004; Salado & Fondebrider, 2008). Starting in 1984 with the support of the American Association for the Advancement of Sciences (AAAS), and particularly of Clyde Snow, forensic anthropology began to play a fundamental role in the political and humanitarian context of the region (Salado & Fondebrider, 2008). Since then, the use of forensic anthropological analysis in South America has been invaluable support for the emotional recovery of the victim’s relatives (Fondebrider, 2016), and in criminal prosecution of those involved in killing and body disposal (Fondebrider, 2016; A. Guzmán & Sanabria Medina, 2016).

In addition to cases that arrive daily for forensic analyses, there are mass fatality events such as natural disasters, terrorist attacks, large-scale accidents, and crimes against humanity that result in thousands of unidentified corpses, and individual and collective mourning processes (Mundorff et al., 2015). In such situations, all forensic sciences have the difficult task of accelerating and improving the identification process, despite budgetary constraints, to reach as many positive identifications as possible. The role of the forensic anthropologist in mass disasters includes, but is not limited to: identification and mapping of human remains at the scene; separation of osseous from non-osseous material; identification of human and non-human remains; identification and management of commingled human remains; assessment of biological profile, and assistance in the reconstruction of the manner of death (Blau & Briggs, 2011; de Boer et al., 2019; Mundorff et al., 2015).

Positive identifications of skeletonized human remains are generally confirmed by dental records and DNA profiles. However, in cases where the DNA is severely degraded, the dental evidence is missing, or antemortem records and DNA profiles to compare to are not available it is necessary to rely on a combination of evidence such as personal belongings, the testimony of witnesses, and a set of unique characteristics observed on the skeleton to determine identity (Baraybar, 2008; Cunha, 2006; de Boer et al., 2020; Kimmerle, Jantz, et al., 2008). This stimulates forensic anthropologists to review existing techniques and propose new ones; thereby improving quality of the results and reducing the margin of error (Baraybar, 2008; de Boer et al., 2020; Ubelaker, 2018b). The success and consistency of the results of forensic anthropologists and the improvement in analysis and reporting, has resulted in the recent recognition by International Committee of the Red Cross (ICRC) of unique skeletal or medical traits as means of personal identification (de Boer et al., 2020; International Committee of the Red Cross, 2020).

1.1.2. Identifying skeletal remains

Identification is a legal determination, in which the forensic expert verifies that "unique features are shared between recovered remains and known antemortem characteristics of a missing person" (Ubelaker 2014:150). It is a two-step process that begins with the positive match between the antemortem and postmortem sets of data, both sets of data of equal importance. Antemortem records such as radiographs, MRIs, and CT scans are ideal sources for comparison with skeletal features, but they are not always available or updated. In their absence, records such as photographs, medical history, and relative's testimonies become the primary source for comparison (Komar & Lathrop, 2006). Traumatic events can be reported by blood and non-blood relatives, increasing the factors subject to antemortem – postmortem comparison. The second stage of the process is to validate the strength of the results (Ubelaker, 2014).

Forensic anthropologists assist in the identification process of human skeletons by narrowing the possible matching identities based on the assessment of the four basic biological characteristics (sex, age, ancestry, height) and provide evidence of individual osteological features including trauma, prosthetic devices, and certain pathologies, that could strengthen identification processes for fully skeletonized individuals (Cunha & Cattaneo, 2018; de Boer et al., 2020). Image, anthropometric measures, bone and sexual maturity, and gait patterns are the most common methods used to assess the living (Obertová et al., 2019)

Forensic anthropology, like any other forensic science, has constantly adapted its aims and procedures to meet social, scientific, and technological requirements. As described, identification has been the principal focus of FA since its early practice, and despite developments in genetics and forensic dentistry, identification continues to be the main goal of FA (Cunha & Cattaneo, 2018). The identification process in FA can be improved by strengthening the methods that provide correlation between the greatest number of traits in antemortem registries and traits found in bone remains (Christensen et al., 2017; Cunha & Cattaneo, 2006). There is not a specific number of common skeletal traits, or a clear characteristic that such traits must have, to be considered sufficient evidence for positive identification. This is also the case in forensic dentistry (Forrest, 2019). Rather, the value of the anthropological and dental identifier relies on the statistical probabilities supporting the uniqueness of a given trait (Cunha & Cattaneo, 2006; Forrest, 2019; Steadman et al., 2006; Ubelaker, 2014).

Identification based on skeletal features is more challenging to support through scientific evidence than DNA or fingerprints because there are nearly infinite possibilities of skeletal and soft tissue alterations that negatively impact the calculation of probabilities (Grivas & Komar, 2008), but having a closed synchronic system (when a single event causes a finite number of victims in a specific circumscribed area e.g., airplane or train accident) increases the probability of positive identifications based on unique skeletal features combined with facts obtained during the preliminary investigations (Baraybar, 2008; Ríos et al., 2012). Several forensic cases around the globe have shown that strong anthropological identifiers can be enough to rely on for personal identification, especially when the traditional methods are limited (de Boer et al., 2020) e.g., Kosovo (Baraybar, 2008; Djurić, 2004); Spain (Ríos et al., 2010); Israel (Kahana et al., 2002); Colombia (Sanabria Medina, 2002).

1.1.3. Forensic anthropology testimony

The practice of forensic sciences has become more rigorous since the decisions in a trilogy of legal cases of *Daubert (Daubert v. Merrell Dow Pharmaceuticals 1993), Kumho* (*Kumho Tire Co. vs Carmichael 1997*) and *Joiner* (*General Electric Co vs Joiner 1999*) lifted scientific requirements for both the method used and the expertise of the practitioner, to be admissible in the United States courtrooms. The same standard was recently incorporated in the Colombian judicial system by Criminal Law 906 of 2004 (A. Guzmán & Sanabria Medina, 2016). In a broad sense, the *Daubert* criteria (listed below) ensures that the scientific testimony is reliable and relevant; while the *Kumho* decision recognizes the wide spectrum of scientific inquiry that can be admissible and the *Joiner* decision requires that an expert's conclusion is sufficiently connected to the evidence (Christensen & Crowder, 2009).

Daubert guidelines (Taken from Christensen & Crowder, 2009)

1. Has the theory or technique been tested?
2. What is the known or potential rate of error?
3. Do standards exist for the control of the technique's operation?
4. Has the theory or technique been subjected to peer review and publication?
5. Has the theory or technique been generally accepted within the relevant scientific community?

Court cases have highlighted that scientific evidence is highly diverse between forensic disciplines with some, such as skeletal traits, relying on observational data where casework experience is relevant. Although these types of evidence do not always meet all *Daubert* criteria, any given conclusion must be the result of scientific procedure that relies on methods approved by the relevant scientific community. Judges are aware that there is diversity in types of evidence and that supported scientific conclusions affect court decisions. Therefore, evidence rules ensure that a method is admissible only after it has been evaluated for admissibility in its appropriate context to assure repeatability and relevance (Christensen & Crowder, 2009).

Due to the *Daubert* guidelines, anthropologists' efforts have focused on quantifying the traditional macroscopic observations for the assessment of three of the four basic biological profile elements, through the use of software for ancestry estimation such as FORDISC (Jantz & Ousley, 2015) or ANCESTREES (Navega et al., 2015), or age estimation using probabilistic sex diagnosis known as the DSP method (Murail et al., 2005). The development and updating of population-based formulas for stature estimation (De Mendonça, 2000; Jantz & Ousley, 2015; Mantilla Hernández et al., 2009), along with new techniques to quantify the uniqueness of bone variability for identification purposes (Christensen, 2005a; Kahana et al., 2002; Mann, 1998; Maxwell & Ross, 2014; Quatrehomme et al., 2014; Yoshino et al., 1987), have created a stronger statistical basis for reporting and testifying in court in keeping with forensic standards.

The forensic anthropology expert must deal with human variation, which is both the strongest feature of FA by providing uniqueness of a skeletal trait for identification purposes, and the weakest point when struggling to demonstrate, statistically, the uniqueness of the same skeletal trait. Human variation provides subjectivity to the evidence, but "subjectivity does not necessarily equal unreliability" (Christensen & Crowder, 2009:1214). Some methods are highly valuable because they may be the only way to collect key information, but usefulness depends on the conservation and quantity of skeletal material available (Christensen & Crowder, 2009; Grivas & Komar, 2008). Therefore, skeletal traits are strong evidence when the data collection has been tested for inter and intra observer repeatability, the analysis conducted is objective and has been correctly argued, and the report is consistent with the evidence, which includes reporting limitations of results.

As explained above, the methodology must be reliable and relevant and implemented by an expert practitioner. Proper training and certification of proficiency increase the legitimacy of testimony, and in turn, the possibility that evidence is admissible in the courtroom (Christensen & Crowder, 2009). Forensic anthropologists are rarely called upon for courtroom testimony, but they are frequently involved in the legal process either by working in conjunction with the pathologist or because the report presented by the anthropologist serves as the basis for the analysis of other experts (Rainwater et al., 2012). Nevertheless, forensic anthropologists must be trained to testify in court and their report must meet the standard requirements.

In conclusion, the current rules of admissibility stimulate forensic anthropologists to review the methods used and explore new ones, either to enact or restrict their use, but all methods must demonstrate validity and statistical repeatabilityand be forensically applicable (Christensen & Crowder, 2009). The use of EC has been limited, almost absent, within forensic anthropological analysis, but its potential usefulness is worth exploring under standardized methodologies and recognizing the limitations of the results.

1.1.4. Forensic Anthropology in Colombia

In the last 50 years, many Latin American countries have experienced large-scale violence associated with dictatorships, civil war, and violence related to drug-trafficking e.g., Colombia, Argentina, Guatemala, Peru. Colombia has a long history of violence, starting in the middle of the 20th century with political violence that triggered an internal conflict, followed by the violence perpetrated by drug-cartels from the 1970s through the 1990s, and the current drug-related violence with political overtones (Franco et al., 2006). The exact number of fatalities in Colombia is unknown due to the length and magnitude of the internal conflict, and the direct involvement of the state as a perpetrator. However, victim's associations and State processes for the recognition of victims have determined that 218,094 people were killed from 1958 to

2012, most of whom were civilians (81%) (Centro Nacional de Memoria Histórica, 2016). Forced disappearance cases total 60,630 people from 1970 to 2014 (Centro Nacional de Memoria Histórica, 2016), but calculations rise to 82,998 individuals when the timeframe is enlarged to 1958 to 2017, and cases documented by the Justice and Peace Law are included[1] (Centro Nacional de Memoria Histórica, 2020).

Anti-personnel mines or explosive remnants of war were frequently used by the FARC, as well as its successor groups, and have injured or killed 12,062 persons in Colombia, 40% of the victims were civilians with limited access to medical aid. Of these, 80.7% suffered non-fatal injuries (Asistencia Integral a las Victimas de Minas Antipersonas., 2021; Centro Nacional de Memoria Histórica & Fundación Prolongar, 2017). As expected, 98% of the reported events occurred in rural areas, 50% of these events occurred in 5 departments (Figure 1-1) that are disproportionately impacted by armed conflict: Antioquia, Meta, Nariño, Caquetá, and Norte de Santander (Centro Nacional de Memoria Histórica & Fundación Prolongar, 2017).

Figure 1-1. Map of Colombia indicating the departments where most of the anti-personnel and explosive remnants of war are located. Black stars indicate location of two hospitals reporting prevalence of non-fatal injuries.

As part of the 2005 demobilization agreement with the United Self-Defense Forces of Colombia (Autodefensas Unidas de Colombia- AUC for the group´s original Spanish title), the

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[1] Updated number of victims was published on CNMH website, but no details regarding the victim’s profile were updated.

group provided the burial locations of more than 10,000 of its victims' human remains which were recovered from 2005 to December 2020 (GRUBE 2020). Nevertheless, the location of thousands of their victims remain unknown. This situation has resulted in an extraordinary number of skeletonized cadavers recovered in the past two decades in Colombia, putting pressure on both the Colombian forensic teams and the protocols used as victims' relatives, Colombia society at large, and international organizations, await positive identifications (Díaz & Urueña, 2020; Sanabria Medina & Osorio Restrepo, 2015). Most of the corpses are fully skeletonized due to the time elapsed between the deaths and recoveries of the remains. As such, forensic anthropology is one of the most frequently required professions for assisting in identification and the manner of death (Centro Nacional de Memoria Histórica, 2016; Sanabria Medina & Osorio Restrepo, 2015).

The National Center for Historical Memory (Centro Nacional de Memoria Histórica -CNMH) reports that in 52% of the cases the perpetrator is known. The former paramilitary groups are responsible for the highest number of forced disappearance cases (62.3%). The Law 975 of 2005, commonly known as "Justice and Peace Law (JPL)", established a special unit of the general Prosecutor's office to locate, exhume, and identify victims of former paramilitaries[2]. The process of exhumation and identification of victims as part of the JPL began in 2007. As of December 2020, a total of 10,001 bodies have been recovered, of which 46.7% were identified and 16.6% have a presumptive identification. i.e., only 16.7% out of the total forced disappearance cases executed by paramilitary groups are positively identified and 6.1% are pending confirmation.

After the JPL, the confessions of former paramilitaries have confirmed that dismemberment of living victims was frequently used as torture (Centro Nacional de Memoria Histórica, 2018). Forensic reports of more than 4,000 burial sites characterized graves as individual or collective, i.e., more than one individual per grave. Mass graves had up to five fully skeletonized individuals, and bodies were found articulated, disarticulated, commingled and/or incomplete (Morcillo-Méndez & Campos, 2012:6-7). Another widespread practice of paramilitary groups was to dispose of complete or dismembered bodies in clandestine cemeteries that were later hidden by artificial or natural landscape elements such as lakes, agricultural crops, or wild

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[2] After the peace agreement signed with the FARC in 2016, the unit was renamed the "Internal Working Group for Search, Identification, and Delivery of Missing Persons –GRUBE". To date, exhumations of the victims of the FARC have not begun; therefore, statistics of this group are only evidence in crimes of the paramilitaries.

vegetation. Rivers and ravines were also used as body disposal sites, especially in cases where the individual was first abducted (Gómez & Patiño, 2007).

Despite having reached peace agreements with two of the biggest groups of perpetrators, the AUC, and Revolutionary Armed Forces of Colombia (Fuerzas Armadas de Colombia -FARC for the group´s original Spanish title), the internal conflict is far from over. Meanwhile forced disappearances, massacres, and selective killings continue to increase the number of victims (Díaz & Urueña, 2020), and expanding survivors´ fear of retaliation if they report the disappearance of a relative or if they provide any information or a DNA sample that could give the impression of collaborating with an ongoing investigation, or if they participate in the truth and reconciliation processes (A. Guzmán & Sanabria Medina, 2016; López, 2020). Doing post-conflict work within an active conflict complicates the already complex task of identification and determination of cause and manner of deaths (El Espectador, 2020).

All mortuary practices described make the recovery and analysis of bone remains problematic. In addition to the complications that the armed conflict brings to personal identification, there are also hundreds, if not thousands, of John and Jane Does that have been lost in the bureaucratic disorder of local cemeteries (Gómez & Patiño, 2007; Sanabria Medina & Osorio Restrepo, 2015). Nevertheless, Colombian forensic teams strive to strictly follow the international protocols for forensic identification of human remains (Gómez & Patiño, 2007).

The Colombian standards for forensic identification state that positive identification is officially declared by the pathologist, but it is an interdisciplinary process that requires that unique traits are shared between antemortem and postmortem records. The contributions of molecular genetics, odontology, dactyloscopy, and anthropological analyses are the main sources upon which to base positive identification, but it is expected that identification is the result of the analysis of several types of evidence and not the conclusion of a single method (INMLCF, 2016). Most of the fatalities related to the internal conflict are individuals from the most remote areas of Colombia, where medical assistance is insufficient or non-existent (Ministerio de Salud y Protección Social, 2018). In these communities, dental consultations are rare, and often dental records are incomplete (Marín & Moreno, 2004). Additionally, access to medical imaging is extremely poor, and given the high rate of internal displacement, it is much less likely that living relatives have the image records available. Therefore, antemortem data supporting dental treatments or pre-existing conditions are limited.

Considering the complications of collecting medical antemortem data and genetic profiles to compare remains with, and to the astronomical number of missing and dead reported and unreported in different regions of the country during the armed conflict, the Colombian identification teams had to improve their preliminary investigation processes and anthropological methodologies to narrow possible identities of victims, and only later, send them for genetic confirmation (López, 2020). The protocol described has achieved a high percentage (73%) of presumptive identities before genetic comparison (Arango-Rodríguez & Camargo, 2015).

Forensic practitioners in Colombia have adjusted published methods of FA to Colombian variability and have created population-based standards to produce more reliable results (Mantilla Hernández et al., 2009; Monsalve & Hefner, 2016; Rivera-Sandoval et al., 2018). For this purpose, two identified bone collections are available in Colombia, one located in the University of Antioquia (UdeA for its Spanish initials) in Medellin, and one held by the National Institute of Legal Medicine and Forensic Sciences (Instituto Nacional de Medicina Legal y Ciencias forenses -INMLCF for its Spanish initials) located in Bogota D.C (Sanabria Medina et al., 2016).

1.1.4.1. Profile of Victims

CNMH reports in 2014 that 87.8% of the documented victims of forced disappearance were male. The victim's age is only known in 20,210 cases (33.3%), with the majority between 18-35 years old (58.6%), followed by individuals between 36-55 years old (20.8%). The occupations of victims are documented in only 8.6% of cases, making it one of the least documented aspects of an individual's life (5231 cases). However, most victims were from rural farming populations where poor living conditions involve high levels of physical activity, and/or lived in zones with active landmines and armed conflict (Equipo Nizkor, 2000) that increased the likelihood of antemortem injuries. Occupations documented by CNMH provide a general idea of likely occupation distribution (Figure 1-2).

The number of non-identified cadavers is 34,743 (LIFE-INMLCF retrieved on November 24, 2021), 79.8% male, 13.5% female, and 6.8% undetermined. Age range distribution has the same patterns as the forced disappearance estimates, where the 18-35 age group is by far the most numerous (63.7%), followed by 36-59 years (16.3%). Male individuals from 18-35 years are the group with the most cases of non-identified cadavers (53.8%).

On the other hand, the lack of economic resources and the limited availability of formal medical assistance in the vicinity result in a high percentage of injuries that do not receive medical treatment (de Becerra, 2013; Ministerio de Salud y Protección Social, 2018). Instead, rural inhabitants who are often unable to spend the time or money to travel to the nearest medical center often rely on traditional healers or *"sobaderos,"* also called sobanderos," who use manual techniques to treat muscle injuries and fractured limbs (Fonnegra et al., 2013; Orozco et al., 2020). Although people affirm that traditional treatment is painful but effective (Fonnegra et al., 2013), there are no official reports of the long-term effects that this type of medicine has on the musculoskeletal system. Moreover, muscle injuries without completed medical treatment can increase the lasting effect of trauma on the musculoskeletal system (Østlie et al., 2011), which make these types of injuries potentially useful for narrowing the universe of victims during the personal identification process, particularly in those cases where there is testimony from family members about traumatic events such as blows or falls.

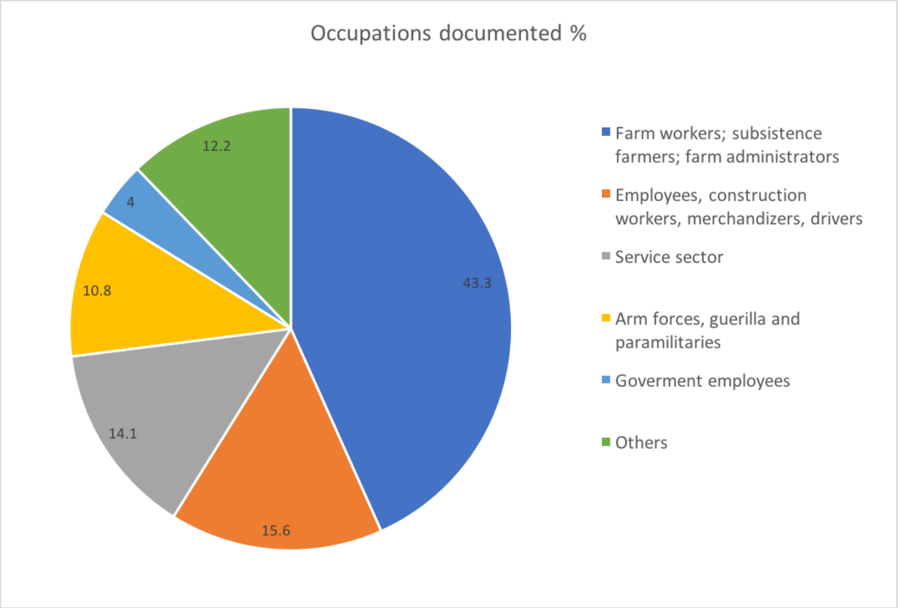


Figure 1-2. Distribution of occupations carried out by the victims of the armed conflict at the time of death. 5231 of total occupations documented (CNMH 2014).

The profile of unidentified cadavers indicated that efforts to strengthen identification methods should focus on male individuals ranging from 18-59 years. Given the large number of victims, the few forensic teams responsible for identifications have done a remarkable job, but additional professionals and better techniques are required to expedite results while maintaining reliable procedures without an overly burdensome increase in cost.

1.2. Skeletal evidence of antemortem injuries

Antemortem injuries are those produced before death and include damages to soft tissue and bone tissue, such as healed fractures, scars, and old lesions. However, forensic anthropology diagnoses antemortem trauma only when bone repair is evidenced microscopically or macroscopically (Cunha & Pinheiro, 2016). For the purposes of this research, antemortem trauma will be considered only when bones evidence macroscopical repair and/or when secondary reactions of the bone such as pseudoarthrosis and myositis ossificans traumatica are present (further description in Chapter 2), unless otherwise stated.

1.2.1. Skeletal evidence of trauma

The effect of trauma on human bones is a complex subject that involves the analysis of external factors, e.g., velocity, magnitude, and duration of the force, that interact with intrinsic factors such as age, bone health, and prior pathological conditions (Symes et al., 2012). Several investigations have been conducted on this topic, mainly regarding bone regeneration for clinical purposes (Einhorn, 2005; Giannoudis et al., 2011; Marsell & Einhorn, 2011; Rickert et al., 1998), and fracture morphology in wet and dry bone for forensic purposes (Özkaya & Nordin, 1999; Symes et al., 2012).

Despite the relevance of muscle health to fracture recovery (K. Davis et al., 2015), there are few studies focused on the relationship between muscle injury and bone fracture within medical and osteological research (Johnston, 1962). Although the relationship between EC and trauma has been suggested (Resnick & Niwayama, 1983), to date no analysis exists regarding the connection between traumatic events and entheseal changes.

Bone fractures, avulsion fractures, amputations, myositis ossificans, and dislocations are currently the most distinct evidence of antemortem trauma available on human remains.

1.2.1.1. *Bone fractures*

Bones are composed of inorganic and organic material, -crystals of calcium hydroxyapatite and collagen fibers, respectively- which provide the elasticity and strength that allows them to resist tension and compression forces (Pearson & Lieberman, 2004). However, bones will fracture when abnormal loads exceed the elastic and plastic region (Currey, 2006). Fractures are described as “the result of any traumatic event which leads to a complete or partial break in the continuity of bone” (Grauer & Roberts, 1996:532), with a world incidence of 9-23/1,000 per year (Court-Brown & Caesar, 2006). Bone fractures are the result of either acute trauma, when an excessive amount of kinetic energy is transferred to the bone from an external object (Symes et al., 2012), an overuse, stress, or fatigue fracture, which is associated with fatigued muscles transferring overload to the underlying bone, or pathological fractures that occur when conditions produce abnormal or pathological bone tissue and minor trauma, or any trauma, fractures the bone (Cunha & Pinheiro, 2016). In the first two cases, soft tissue is often damaged thereby complicating the healing process (Johnston, 1962).

Five major types of force act on bone: tension, compression, torsion, bending, and shearing forces. In a broad sense, tensile forces pull bone apart, while compression pushes and squeezes bone together. Torsion forces twist the bone about its longitudinal axis. Bending, or flexion force, is a combination of tension and compression forces, acting on opposites sides that cause bone to bend. Shear force acts parallel to a surface sliding one portion of the bone with respect to another portion (Symes et al., 2012; Wedel & Galloway, 2013). Biomechanical studies have established basic principles for the analysis of bone reactions to trauma, but bone fractures involve a combination of more than one force acting at the time, plus other factors such as magnitude, direction, duration of the forces, environmental factors, geometry, and mechanical properties of the bone. Although fractures are categorized into five types according to the forces involved (Table 1.1), mechanical properties of bone tissue differ from bone to bone, in relation to type of bone (e.g., long bones vs flat bones), and the location in the bone (e.g., diaphysis vs metaphysis). Therefore, engineering principles of fracture mechanics have a limited application in bone fracture analyses (Currey, 2006; Symes et al., 2012).

Table 1-1. Description of different types of bone fracture (Gozna 1982; Tencer 2006). Taken from Symes et al. 2012

Fracture	**Description**
Transverse	Bone fractures across the diaphysis of the bone at 90° angle. A pure tension fracture occurs in experimental situations but not in real-life injuries.
Oblique (transverse)	Bone fractures at approximately a 45° angle, consequence of bending and compression.
Butterfly	Bone fractures as a result of tension, compression, and bending forces. Bone is stronger in compression than tension. Bone breaks into two pieces with one triangular fragment and two segmental fragments.

Spiral	Bone experiences extreme torsion. The fracture encircles the bone shaft and creates an oblique-like break around the bone axis.
Comminuted	Bone fractures into two or more pieces.

Physical activity is one of many causes of antemortem trauma, especially when the hours are long and loads are excessive, as occurs in agricultural farming activities in Colombia (Aristizabal, 2013). The clinical (Postuma de Boer et al., 2016) and paleopathology literature (Judd, 2008; Merbs, 1996a; Tucker et al., 2017) has associated specific activities with patterns and distribution of fractures e.g., clay-shoveler's fracture, boxer's fracture, Parry's fracture. However, patterns of activity generally cannot be reconstructed based on bone fractures alone (Jurmain, 2013a; Stirland, 1996).

Clinical reports show that injuries involving soft tissue are more frequent than bone fractures, and that prevalence of injuries changes depending on the type of medical center treating the injury (e.g., rural, urban, or military), and the geographical region (Haagsma et al., 2016). For instance, in Santa Marta, on the northern coast of Colombia (Figure 1-1), traumatic fractures account for 8.5% of the visits to the emergency room for 1 year (del Gordo D´Amato et al., 2005). While in Medellin, traumatic fractures caused 1.7% of the visits in the same period, and soft tissue injuries reach 7.7% (Table 1-2). Estimates of traumatic fractures in Medellin were similar to those in the USA (1.8%), but soft tissue injuries were two times more frequent in Medellin than in the USA (3.8%) (Rui & Kang, 2017). As seen, muscle injuries are frequent in all contexts, but prevalence of the location and type of injury may be different amongst contexts.

Table 1-2. Statistics of injuries treated in the USA and two cities in Colombia.

Type of injury	**Tissue affected**	**Bone / affected area**	**USA National statistics N:138,977,000**		**Santa Marta-Colombia N:19,107**		**Medellin - Colombia N:259,163**	
			%	**n**	**%**	**n**	**%**	**n**
Traumatic fracture	Bone	Shoulder and upper arm (Clavicle, scapula, humerus)	0.30%	464,000	1.40%	264	0.50%	1,362
		Forearm (ulna and radius)	0.40%	578,000	2.60%	492	0.20%	414
		Wrist and hand (carpal, metacarpals, phalanges)	0.50%	750,000	1.20%	228	1.00%	2,609

		Leg, foot, toes excluding hip and ankle (femur, tibia, patellar, fibula, tarsals, metatarsals, phalanges)	0.50%	674,000	3.30%	632		*
Contusion	Soft tissue	No data	2.30%	3,150,000		*	6.50%	16,932
Dislocations, sprains, and strains	Soft tissue	No data	1.50%	2,147,000		*	1.20%	3,049

Injuries in rural Colombia are mostly related to the armed conflict (Centro Nacional de Memoria Histórica & Fundación Prolongar, 2017; Franco et al., 2006) or farming-related accidents (Aristizabal, 2013). However, as described above (1.1.4.1. section), minor lesions suffered by rural inhabitants in Colombia are often treated by local healers, which underscores the actual prevalence of fractures and other non-fatal lesions.

1.2.1.1.1. Avulsion fractures

Avulsion fractures are skeletal injuries that occur when a fragment of bone is pulled off by a tendon or ligament at its origin or insertion site (Merbs, 1989; Resnick & Goergen, 2005). These types of injuries are caused by tension forces and are often reported in young athletes after a sudden and forceful contraction of the muscle involved (Ruffing et al., 2018). Avulsion forces are common amongst skeletally immature individuals involved in sports because their tendons and ossified bones are stronger than their growth plates (Ruffing et al., 2018). In contrast, avulsion fractures are extremely rare in skeletally mature individuals and require a high-energy trauma (McCoy & Nelson, 2021; Patterson et al., 2018), or a predisposing that affects bone quality such as osteoporosis, neuropathic, diabetic disease, or previous surgical procedures (Porr et al., 2011; Rauer et al., 2018).

Anatomical characteristics of entheses prevent tensile forces from causing damage to the musculoskeletal system (Benjamin et al., 2004). However, muscle overloads can occur virtually anywhere in the body (Resnick & Niwayama, 1983). The most common sites for avulsion fractures in adults are the olecranon, calcaneus, patellar, and tibial plateau (Fallat et al., 1998; Major et al., 2020); while in immature skeletons the most frequent avulsion fractures are the pelvis, tibial tuberosity (called Osgood-Schlatter disease), or distal patella (called Sinding Larsen-Johansson syndrome) (Figure 1-3), and are associated with physical activities involving jumping, running, and kicking (López-Alameda et al., 2012; Mellado et al., 2002; Porr et al., 2011).

Figure 1-3. X-Ray of the knee, showing avulsion fractures of the patella (Sinding-Larsen Johansson) and the tibia (Osgood-Schlatter disease). Taken from Lara, 2017.

1.2.1.2. *Dislocation and subluxations*

Dislocation is defined as "a complete loss of contact between two osseous surfaces that normally articulate" (Resnick & Goergen, 2005:811) and implies damage of the joint capsule and its protective ligaments, and "subluxation is a partial loss of this contact" (Resnick & Goergen, 2005:811). These types of injuries are associated with acute trauma or weak and instable ligaments around joints that cause damage to the soft tissue of the joint (86%) and a smaller proportion of cases involve fractures (14%) (Fallat et al., 1998; Redfern & Roberts, 2019). Dislocation/subluxation in young athletes are reported to be the result of falls and collisions associated with ice-skating, dancing, soccer, running, basketball, boxing, and football. Sports injuries and assaults caused most of the soft tissue injuries, with young male individuals the most affected population (Clayton & Court-Brown, 2008; Lemme et al., 2018; Owens et al., 2017). Clinical literature reports that the most recurrent dislocations are the glenohumeral joint (4-51/100,000), joints of the hand (18-30/100,000), patellofemoral joint (22-24/100,000), hip (19/100,000), ankle (7-40/100,000), acromioclavicular joint (9-14/100,000), and the elbow (3-6/100,000) (Clayton & Court-Brown, 2008; Hindle et al., 2013; Lemme et al., 2018).

Given the lack of skeletal evidence supporting this type of soft-tissue injury, the report and analysis of these disruptions are rarely diagnosed and evaluated by a forensic anthropologist. Dislocations and subluxations can be identified in the skeletal evidence when anatomical changes in subchondral bone or the bone adjacent to the joint are clear, e.g., secondary joint surfaces (Ortner & Putschar, 1985; Redfern & Roberts, 2019).

Victims of human rights violations often exhibited skeletal evidence of dislocations associated with torture methods including electric shocks, direct blows, rotation mechanisms, and mechanical asphyxia. The lack of orthopedic treatment of such injuries, i.e., reduction, causes skeletal changes within 6 months (Rodríguez-Martín, 2006).

1.2.1.3. Amputations

Amputations are absence of the distal segment of the limb, and can be the result of congenital anomalies, diseases (i.e. diabetes), severe bacterial infections (gangrene), frostbite, gunshot wounds, blast wounds, or intentional or accidental cuts (Ahmed et al., 2013; Kirkup, 2007). Perimortem amputations leave clearly defined edges on the bone. Several weeks after the lesion, amputated bones have a soft and rounded end. Years later, the lack of use of the amputated limb can cause bones to be osteoporotic, atrophied, and less robust (Rodríguez-Martín, 2006).

Intentional amputations have been used as a mechanism of torture or punishment in several parts of the world (Rodríguez-Martín, 2006), including Colombia, where its practice was associated with paramilitary groups (see section 1.1.4) as part of their killing routines (Centro Nacional de Memoria Histórica, 2018). Likewise, most limb amputations suffered by soldiers and rural population in Colombia are caused by non-fatal injuries produced by anti-personnel mines or explosive remnants of war associated with FARC's *modus operandi* (see above) (Centro Nacional de Memoria Histórica & Fundación Prolongar, 2017; C. F. Valencia et al., 2015).

1.2.1.4. Muscle injury

Contusion, strain, and laceration are the most common causes of muscle injuries, which frequently affect athletes and non-athletes (Garrett, 1996; Järvinen et al., 2000). Up to 55% of acute sports injuries involve soft tissue (Järvinen et al., 2005), causing significant absences from training and competition, as high as 25% for professional soccer players (Corazza et al., 2013). The research and literature regarding muscle injuries have focused on athletes due to their high impact on the performance of elite athletes. Despite the frequency of muscle injuries treated in medical and sports premises, the literature lacks consensus with respect to definitions and classifications (Chan et al., 2012; Mueller-Wohlfahrt et al., 2013; Pollock et al., 2014). The classification system described below is based on the trauma mechanism and was developed by a group of experts seeking to standardize the terminology used in clinical practice and research (Mueller-Wohlfahrt et al., 2013). This classification system distinguishes two main subcategories, direct and indirect muscle injuries, which in turn are divided into ten well-described different types of soft-tissue injuries: four types of functional muscle disorder, four types of structural muscle injury, and two types of direct trauma (Table 1-3). However, current knowledge of bone tissue reactions to each type of muscle injury limits tracking of the different types of injuries described by Mueller-Wohlfahrt and colleagues based on the dry bone appearance. Thus, this research recognized only the two main categories of muscle injury: direct and indirect trauma.

Table 1-3. Classification of acute muscle disorders and injuries (Taken from Mueller-Wohlfahrt et al. 2013)

A. Indirect muscle disorder/injury	Functional muscle disorder	Type 1: Overexertion-related muscle disorder	Type 1A: Fatigue-induced muscle disorder
			Type 1B: Delayed-onset muscle soreness (DOMS)
		Type 2: Neuromuscular muscle disorder	Type 2A: Spine-related neuromuscular Muscle disorder
			Type 2B: Muscle-related neuromuscular Muscle disorder
	Structural muscle injury	Type 3: Partial muscle tear	Type 3A: Minor partial muscle tear
			Type 3B: Moderate partial muscle tear
		Type 4: (Sub)total tear	Subtotal or complete muscle tear
			Tendinous avulsion
B. Direct muscle injury		Contusion	
		Laceration	

1.2.1.4.1. *Direct muscle injury*

The direct muscle injury category includes the injuries caused by an external force, such as contusions and lacerations (Mueller-Wohlfahrt et al., 2013). Lacerations are rare and dramatic injuries produced by a sharp surface (Oliva et al., 2013). Contusions are direct blows from a blunt surface striking the body, often reported in football, hockey, and soccer players. After muscle tears, contusions are the second most common injuries in contact sports (Beiner & Jokl, 2002). The gastrocnemius and quadriceps are the muscle groups most frequently subject to direct muscle injuries. Contusions are often reported in athletes in the anterior aspect of the lower limbs, whereas contusions in the upper limbs are more associated with the pediatric population (Carlson & Klassen, 1984). Contusions cause internal bleeding and inflammation of the affected area. In some cases, (between 9-17%) complications of severe contusions have been reported to lead to myositis ossificans traumatica (Beiner & Jokl, 2002; Best, 1997; Redfern & Roberts, 2019).

1.2.1.4.1.1. *Myositis ossificans*

Myositis ossificans (MO) is a benign heterotopic ossification of soft-tissue (Ogilvie-Harris & Fornasier, 1980). Two forms of MO are recognized: circumscripta (MOC) and progressiva (MOP). MOC, also known as myositis ossificans traumatic or post-traumatic, is the most common form of MO (approximately 60-75% of all MO cases), and its origin is frequently related to one-off trauma or repeated micro-trauma (Best, 1997; Parikh et al., 2002). However, the etiology is not completely understood and in the 40% of remaining cases, including MOP, no trauma history has been reported (Ogilvie-Harris & Fornasier, 1980; Yazıcı et al., 2002). Predisposition conditions associated with MO are orthopedic surgery, mainly hip arthroplasty (up to 40%), bone fracture or dislocations, mainly elbow trauma (up to 30%), high-energy extremity trauma (up to 60%), traumatic brain injury and other neurological disorders, spinal cord injury (up to 50%), amputations (up to 90%), and third-degree burns (up to 20%) (Forsberg et al., 2009; Meyers et al., 2019).

Combat-related blast injuries have been associated with a high prevalence of MOP (64.4%). Some of the risk factors of developing MOP in wartime injuries are amputations, multiple extremity trauma, injuries that constitute an Injure Severity Score ≥16. The same study found a higher prevalence of MOP in individuals were 30 years old or younger, who are the most common age range in combat contexts (Forsberg et al., 2009). Likewise, local and systemic inflammatory responses following bacterial wound colonization appears to be related to development of MOC in combats wounds (Ahmed et al., 2013; Forsberg et al., 2014).

Myositis ossificans circumscripta has a developmental process that becomes radiologically evident 2-4 weeks after the initial trauma. In the early stage (3-4 weeks) the bone formation is amorphous and flocculent, often accompanied by periosteal reactions (Best, 1997; Walczak et al., 2015). In the six to eight weeks following the trauma, these calcifications mature and become a densely calcified mass in a rim shape that is clearly identified in any radiological test. Between the 4th and 6th month, the MOC has a mature lamellar bone appearance and may begin the reabsorption process. MOC older than 6 months are considered mature lesions that could be surgically treated, however, MOC are often totally reabsorbed, with some exceptions where bone calcification remains for life. The clinical implications of MOC are localized pain, muscle atrophy, and reduction of joint motion (Best, 1997). In most cases, full motion of the affected muscle is recovered, even if bone calcifications remain (Best, 1997; Simon et al., 2016).

MOP, also known as fibrodyplasia ossificans progressiva, is a rare genetic disease that causes progressive heterotopic ossification of muscle, tendon, aponeuroses, and ligaments. (Meyers et al., 2019; Ram, 2015). Its worldwide prevalence is 1/2,000,000. To date only four cases of MOP have been reported in Colombia, all of which showed the classic symptoms: malformations of the first toe, presence of tumor-like masses, and it was diagnosed during the first decade of life (Forero et al., 2011; González & Brand, 2014; Pachajoa & Botero, 2015). Other early signs of MOP are congenital skeletal malformations, such as dysmorphologies of the digits of the hand, and malformations of the cervical spine (Meyers et al., 2019). Individuals with MOP have a life expectancy of 55 years, with a median lifespan of 40 years. However, heterotopic ossifications accumulate by the third decade of life, physically disabling individuals who often require assisted living (Kaplan et al., 2008, 2010).

This research seeks to identify the effect of antemortem trauma in EC, therefore only MOC is going to be addressed. As described, MOP is a progressive disease showing congenital skeletal malformations and pathological ossification of the skeletal muscle and connective tissue affecting first the dorsal, axial, cranial, and proximal regions of the body (Kaplan et al., 2008), while MOC is a solitary and self-limiting ossification typically occurring in the skeletal muscle

(Walczak et al., 2015). Therefore, the two types of MO are skeletally different from one another.

Myositis ossificans diagnosis in dry bones can be mistaken as osteosarcoma and chondrosarcoma, but the location of the lesion is the key factor to differentiate these pathologies (Ortner, 2003; Redfern & Roberts, 2019). MOC are usually located at the insertion or origin of tendons and ligaments (Ortner, 2003) most are found in the flexor muscles of the arm, and extensor muscles of the thigh (Walczak et al., 2015). In contrast, cancerous bone lesions are rare, representing less than 0,2% of all cancers diagnosed (Hameed & Dorfman, 2011), and it is even rarer for them to be focused on the enthesis (Ortner, 2003).

1.2.1.4.2. Indirect muscle disorder/injury

Indirect muscle disorder comprises all muscle disorders not caused by an external force, i.e. overuse, stretch-induced, and exercise-induced injuries (Maffulli et al., 2015; Mueller-Wohlfahrt et al., 2013). Indirect muscle disorders are frequently located in the musculo-tendinous junction and occur during an eccentric contraction of the muscle (Askling et al., 2007). Two-joint muscles such as the quadriceps muscle, the hamstrings, and the medial head of the gastrocnemius, are the muscles most commonly affected by indirect injuries (Best, 1997).

Indirect injuries include both functional muscle disorders and structural muscle injury. Functional muscle disorders refer to any “acute muscle disorder without macroscopic [MRI or Ultrasound] evidence of muscular tear” (Mueller-Wohlfahrt et al., 2013:3), while structural muscle injury involves macroscopic evidence of muscle tear. This type of injury is more frequently reported in non-contact sports such as soccer, running, or any other activity involving sprinting and jumping (Best, 1997; Maffulli et al., 2015).

Strains and sprains are defined as tears in muscle/tendons or ligaments; respectively, thus these types of injuries are included in the indirect injury category. Sprained ankle is the most recurrent injury in both amateur and professional sports practice, reaching 25%-45% of all injuries (Fallat et al., 1998; Hootman et al., 2007). Sprained ankles are the result of stretching and tearing lateral and collateral ligaments due to excessive supination and inversion of the plantarflexed foot while the tibia is externally rotated (Fallat et al., 1998). Long-term unstable ankles are associated with early onset of osteoarthritis (Golditz et al., 2014; Harrington, 1979).

1.3. Compensatory movements

Thousands of different movements are performed daily by humans, which allows us to satisfy basic biological needs as well as other physical routines or to perform intense physical exercise. Individuals are likely to eventually suffer injuries, or have been born with physical limitations, that prevent or restrict normal range of movement. Such restrictions on normal movements generally result in a conscious or unconscious variation of the original movements to maintain physical autonomy. Compensatory movements are those changes in normal motion patterns that allow for the completion of tasks when strength or mobility is restricted (Carey et al., 2008; Higginson et al., 2006; McCrea et al., 2005; Riegger-Krugh & Keysor, 1996).

Restriction on free movement may have a temporary or permanent after-effect on the correct performance of activities of daily living. Minor injuries generally maintain the biomechanical loads inside their physiological limits and therefore cause no major effects on the skeleton. However, studies performed in young and old healthy men showed that muscle disuse significantly reduces skeletal muscle mass and muscle strength within just a few days (Hvid et al., 2013; Wall et al., 2014). Physical rehabilitation is needed to fully recover from injuries, but is usually not available in rural medical facilities in Colombia (Ministerio de Salud y Protección Social, 2018). Therefore, patients either have to travel to the closest medical premises, usually in the main cities, or they decide not to follow the recommended treatment (Pinzón & Peña, 2004). More severe injuries either require additional time for recovery or may compromise an individual’s range of movement for the rest of their life (Østlie et al., 2011). In such cases, it is likely that specific traits associated with biomechanical loads can be found on the skeleton (Carey et al., 2008; Merbs, 1989; Metzger et al., 2012). Apart from standardized skeletal signs of antemortem trauma (SWGANTH, 2011), the skeletal evidence of clear dominant sides is significant morphological or structural differences between bilateral bones. However, such evidence is not strong enough to infer greater biomechanical load in one side compared to the other, and cannot be used in forensic reports (Merbs, 1989; Ubelaker & Zarenko, 2012).

Muscle lesions are highly recurrent injuries in sports that generally do not reach bone tissue but could be painful enough to cause changes in motion patterns that eventually affect the bone despite the absence of fractures or pathologies (Smeulders et al., 2001). Studies performed in soccer players estimate that more than 24% of players suffer injury either in matches or training sessions. Severe injuries are rare, and between 2% and 20% of players will suffer a fracture (Faude et al., 2013; Pangrazio & Forriol, 2016; Vanlommel et al., 2013). The same rate of injuries was found at the professional and amateur levels (Van Beijsterveldt et al., 2013). Likewise, studies performed in other athletes (Bonnard et al., 1994; Notarnicola et al., 2012, 2014) and certain occupations such as sawing (Côté et al., 2002) have shown that muscles of dominant limbs tend to fatigue after repetitive movements. Fatigued muscles change the local parameters of movements (Côté et al., 2002) altering coordination of joints and causing an imbalance of muscle contributions (Bonnard et al., 1994). Such changes may reach the bone tissue by causing stress fractures or stimulating degenerative joint changes in young individuals (Fallat et al., 1998; Maitra & Johnson, 1997).

Compensatory movements may result in distinctive skeletal traits that are worth exploring as forensic evidence because these changes of normal movements can range from unnoticeable to very evident movements that relatives, friends, acquaintances, or neighbors would have noticed and can report. In order to conduct good preliminary research antemortem data forms must elicit details about motion patterns and muscle injuries that can be compared with skeletal changes during the identification process (Cunha, 2006; Rodríguez-Martín, 2006).

1.4. Entheses

Entheses are where muscle, tendons, ligaments, and joint capsules attach to the bone (Benjamin et al., 2002; H. Shaw & Benjamin, 2007). The enthesis has the primary function of joining two materials with different biomechanical properties, hard and soft tissue and making them work in harmony (Currey, 2006). Both materials are viscoelastic, with similar tensile strength (Hems & Tillmann, 2000), but bones have nearly ten times more elastic modulus than tendons, ligaments, and muscles (Currey, 2006; Liu et al., 2012). An enthesis is thus a highly specialized interface that allows smooth transmission of force, maintaining a stable anchorage, and avoiding failure (Benjamin & Ralphs, 1998; H. Shaw & Benjamin, 2007). While two main types of entheses have been identified, fibrocartilaginous and fibrous enthesis (further explained below), each enthesis is subject to unique load levels and variable directional loads depending on the function of the muscle and the location within the bone. Therefore, the shape, size, and anatomy of each enthesis is unique (Benjamin et al., 2006; Benjamin & Ralphs, 1998).

The musculoskeletal system has more than 2000 entheses with different structures that dissipate stress away from the insertion site (Benjamin & McGonagle, 2001) and enhance the strongest features of each tissue (Currey, 2006). The most frequent entheseal structures are:

i) entheses that intermingle and overlap one another to reinforce anchorage security e.g., linea aspera (Benjamin et al., 2004);
ii) the existence of adjacent structures that share functions similar to the enthesis itself, i.e., “enthesis organs”.
iii) entheses that cover large areas in order to limit the degree of muscle stretching and to reduce stress concentrations (Knese & Biermann, 1958, cited by Benjamin et al., 2004);
iv) and the same muscle attached to multiple bone points before reaching the enthesis (Benjamin et al., 2004).

Benjamin and McGonagle (2001) observed that tendons and ligaments often dissipate stress away from the enthesis by contacting the bone just before reaching the insertion point. This led them to develop the concept of an “enthesis organ” to describe the set of tissues at and near the insertion point that works together with the enthesis itself to reduce stress away from a single focused attachment. An enthesis organ comprises adjacent structures such as bursas, fat-pads, sesamoid fibrocartilage, periosteal fibrocartilage, bone tuberosities, and fascia that strengthen the enthesis itself (Benjamin et al., 2004).

Few authors have addressed the anatomical and physiological characteristics of the entheses itself from the clinical perspective, and their studies are mostly linked to the relationship between enthesophytes and diseases such as spondyloarthropathies and diffuse idiopathic skeletal hyperostosis (DISH) (Benjamin et al., 2006; Benjamin & McGonagle, 2001; H. Shaw & Benjamin, 2007). Although the entheses are a fundamental part of the musculoskeletal system, and surgical reattachment of tendons and ligaments are an important and frequent procedure in sports medicine, occupational health, and geriatrics, amongst other medical specialties (Benjamin et al., 2006; Derwin et al., 2018), few studies have focused on the relationship of entheseal changes to sex, age, BMI, physical activity, and rheumatic diseases from a clinical perspective with *in vivo* patients (Aydin et al., 2010; Bakirci et al., 2020; Czegley et al., 2018; I. Eshed et al., 2007; McGonagle, Marzo-Ortega, O’Connor, Gibbon, Pease, et al., 2002). Without further studies, the reaction of entheses to biomechanical loads, and other questions, remain inconclusive (Bakirci et al., 2020; Masi et al., 2021; Solmaz et al., 2021). Additional clinical research is imperative to the understanding of the etiology of each of the changes observed on the dry entheseal surface.

1.4.1. Type of entheses

There are two types of entheses depending on the tissue present, fibrous (FB) and fibrocartilaginous (FC) (Benjamin & Ralphs, 1997, 1998), or indirect and direct entheses, respectively, following Woo & Buckwalter's (1988) terminology. This research uses the terminology proposed by Benjamin and colleagues (1997, 1998), fibrous and fibrocartilaginous entheses, because it more accurately reflects the anatomical difference between the two types of entheses, and it has been used in the osteological research (Henderson et al., 2013).

1.4.1.1. *Fibrous enthesis*

Fibrous entheses connect tendons and ligaments either directly to the bone or indirectly via the periosteum, through dense fibrous connective tissue (Benjamin et al., 2006; Woo & Buckwalter, 1988). Usually, this type of enthesis is most commonly found at metaphyses , inserted at a distance from the joint, which limits the changes in the insertion angle while moving, and reduces compressive forces because tendons are not twisted (Benjamin et al., 2006). FB entheses anchor powerful muscles such as the deltoid over a large area, leaving a large, poorly defined, and irregular footprint on the bone (Villotte et al., 2016). Given its irregular normal appearance, it is difficult to develop standardized recording methods for EC analysis (Villotte et al., 2016; Villotte, Castex, et al., 2010).

1.4.1.2. *Fibrocartilaginous enthesis*

Fibrocartilaginous entheses are characterized by a smooth surface, well-delimited boundaries, and lack of avascular foramina (Benjamin et al., 2006). FC entheses are in apophyses and epiphyses of long bones. Given that joints have a broader range of movement than diaphyses, the insertion angles of the muscles change significantly during motion of the joints increasing the exposure of fibrocartilaginous enthesis to overuse injuries (Benjamin & Ralphs, 1998). This type of enthesis does not have periosteum to connect to, thus ligaments and tendons are directly connected to the bone (Woo & Buckwalter, 1988). The structure of FC entheses vary, but generally this type of enthesis has four histological zones: i) dense fibrous connective tissue, ii) uncalcified fibrocartilage, iii) calcified fibrocartilage, and iv) bone. An avascular calcification, or tidemark, separates the uncalcified from calcified fibrocartilage (Figure 1-3). Each zone contains a different type of collagen that appears to balance the different moduli of elasticity between hard and soft tissue (Benjamin et al., 2002, 2006; Benjamin & Ralphs, 1998). As described above, FC entheses vary structurally from region to region. “One or more [of the histological] zones can be locally absent” (Benjamin et al., 2007), which shows the complexity of the enthesis structure, and the methodological error of pooling them together for analysis without acknowledging their unique anatomy and physiology. Despite this variability, the appereance of a normal FC enthesis is easy to define at a macroscopic visual level.

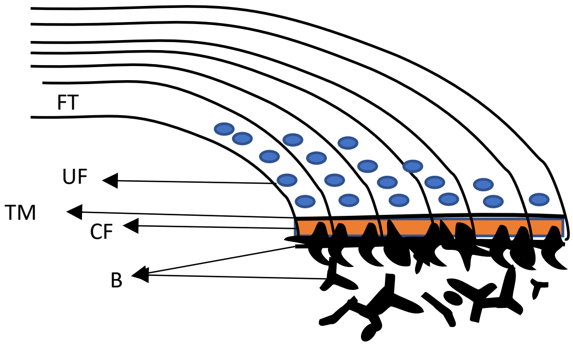


Figure 1-4. Anatomy of a typical fibrocartilaginous entheses. B= bone, CF=calcified fibrocartilage, UF=uncalcified fibrocartilage, TM= tidemark, FT= fibrous connective tissue. Modified from McGonagle & Benjamin (McGonagle & Benjamin, 2015)

Given the greater knowledge of their anatomy and physiology, the fibrocartilaginous entheses are more appropriate to record and analyze for forensic identification purposes than fibrous entheses. Considering the lack of standardized methods for recording, and the important gaps in the understanding of the fibrous enthesis, this analysis uses only the most studied fibrocartilaginous entheses.

1.4.2. Entheseal Changes in dry bones.

The abnormal appearance of entheses, first led to the exploration of the relationship between physical activities and skeletal markers in by William Turner in 1886, and William Lane in 1888 (Kennedy, 1989). Lawrence Angel analyzed occupational stress markers in both archaeological (Angel, 1946, 1966; Kelley & Angel, 1987) and forensic human remains to infer constant physical activities (Angel & Caldwell, 1984; Grisbaum & Ubelaker, 2001). Between the 1980s and 1990s, the first systematic analyses were performed (Crubézy, 1988; Cunha &

Umbelino, 1995; Dutour, 1986; Kelley & Angel, 1987; Molleson, 1994; Peterson, 1995; Stirland, 1993) but EC became an attractive research topic after the publication of Hawkey and Merbs (1995), because a visual method was proposed and their study stated that entheseal changes were related to increased physical activity. The symposium *Activity Patterns and Musculoskeletal Stress Markers: An Integrative Approach to Bioarchaeological Questions,* held in St. Louis, Missouri in 1997 (Peterson & Hawkey, 1998), and the *Workshop in Musculoskeletal Stress Markers (MSM): limitations and achievements in the reconstruction of past activity patterns*, held in Coimbra, Portugal in 2009 (Santos et al., 2011), revealed a growing interest in this topic, and allowed a thorough evaluation of the advances achieved since the first studies, especially the lack of ability to infer specific physical activities based on the skeletal markers e.g., shoemaker, horse rider (Kennedy, 1998). Both meetings also evidenced fundamental issues that had to be addressed. The most relevant were the unclear theoretical and biological bases of EC, the lack of standardization of the recording methods, and the role played by factors, particularly age, on EC (Peterson & Hawkey, 1998; Santos et al., 2011).

The Coimbra Workshop in 2009, highlighted the need for a standardized terminology (Santos et al., 2011). Jurmain and Villotte (2010) proposed the term “entheseal changes” to replace what previously was described as “activity-induced pathology” (Merbs, 1983), “enthesopathies” (Dutour, 1986), “skeletal markers of occupational stress” (Kennedy, 1989), and the most popular term “musculoskeletal stress markers” (Hawkey & Merbs, 1995). Jurmain and Villotte intended to propose a neutral term that applies to both pathological and non-pathological cases without implying a cause (e.g., occupations), specific nature (e.g., degenerative), or aspect (e.g., crest).

Entheseal changes are all macroscopical changes observed, with the naked eye, on the normal enthesis surface (Henderson et al., 2013; Villotte, Castex, et al., 2010). These skeletal markers have been the focus of several studies during the last decades, mainly because of their apparent relationship to activity (Havelková et al., 2011; Hawkey & Merbs, 1995; Jimenez-Brobeil et al., 2011; Milella et al., 2012; Villotte, Castex, et al., 2010). However, evidence has indicated that such changes are less associated with physical activity than initially thought. Several studies have demonstrated that ECs have a multifactorial etiology influenced by factors such as age (Alves Cardoso & Henderson, 2009; Cunha & Umbelino, 1995; Henderson, Mariotti, et al., 2017), sex hormones (Weiss et al., 2012; Wilczak, 1998), genetic predisposition (Wilczak, 1998), body size (Michopoulou et al., 2015; Weiss, 2007), pathologies (Henderson, 2008), and biomechanical loads (Michopoulou et al., 2015).

Considering that bone tissue responds to internal and external factors by forming or destroying bone cells and that mineralized cartilage may alter the entheseal surface, researchers have standardized three main categories of entheseal changes: 1) mineralized tissue formation; 2) surface discontinuity; and 3) complete loss of original morphology (Villotte et al., 2016). The first category comprises all changes that exceed the original surface height, which includes both the changes that are not clearly distinct from the surface (e.g., textural change), and the ones that are a distinct protrusion (e.g., enthesophytes). The second category involves changes that affect the continuity of the cortical surface, mineralized cartilage, or subchondral bone, such as porosity and erosion. The third category refers to mixed changes that cause complete loss of the original surface (Villotte et al., 2016).

Researchers have strived to standardize the recording of EC (Hawkey & Merbs, 1995; Henderson et al., 2013, 2016; Mariotti et al., 2004, 2007a; Villotte, 2006). Their efforts have raised awareness regarding appropriate biology and repeatability of the recording method when analyzing entheses (Henderson et al., 2016; Wilczak et al., 2017). Considering the lack of understanding of enthesis physiology and anatomy, the results of EC analysis cannot be interpreted as evidence of one single factor like activity levels or aging (Jurmain et al., 2012).

Robusticity is a characteristic that describes the expression of entheses, mostly used for fibrous entheses, and can range from “normal” to strong markings (Hawkey & Merbs, 1995; Mariotti et al., 2007a). Forensic anthropology has used robusticity of muscle markers as a general indicator of activity levels, without attributing an EC to a specific activity pattern (Cunha, 2006; Kennedy, 1998). Additionally, robusticity has been complementary evidence of overall estimation of sex, where individuals with higher body mass that have been normally attributed to male individuals, have stronger muscle markers (Cabo et al., 2012; Godde et al., 2018). Forensic anthropologists have also relied on pathological ECs to support early stages of rheumatic diseases and/or DISH in cases of personal identification of middle adults (Cunha, 2006). Most recently, the analysis of EC has been considered potentially useful in estimation of age in individuals older than 60 years (Listi, 2016).

1.4.2.1. *Etiology of entheseal changes*

The Coimbra method is focused on the fibrocartilaginous entheses and clearly describes the most frequent features found at the fibrocartilaginous entheses. Therefore, the following types of entheseal changes were described based on the definitions provided by this method and the terminology proposed by Villotte and colleagues (2016). Three main types of changes are characterized: mineralized tissue formation (e.g., bone formation and textural change); surface discontinuity (e.g., erosion, porosity and cavitation), and complete loss of the original morphology (Villotte et al., 2016).

1.4.2.1.1. Mineralized tissue formation

1.4.2.1.1.1. Isolated protrusion

An isolated protrusion is a clearly distinct bone formation of any size and shape that arises from the original surface of the enthesis (Henderson et al., 2016; Villotte et al., 2016). Osteological and clinical literature refers to this type of change as enthesophyte or new bone formation (Czegley et al., 2018; Henderson et al., 2016; Schett et al., 2017; Villotte et al., 2016)(Figure 1-5b), and is the most common feature observed in the entheseal surface (Wilczak et al., 2019). The presence of bone formation in some entheses in the upper limbs has been largely attributed to aging (up to 44% according to Henderson et al., 2017), and is associated with tension and compression forces (Benjamin et al., 2000; Czegley et al., 2018; Jacques et al., 2014; Kumai & Benjamin, 2002), as well as high BMI (Bakirci et al., 2020; Godde & Taylor, 2013) in entheses in the lower limbs. Enthesitis, associated with psoriatic arthritis and spondyloarthritis genetic predisposition, appears to be triggered by low thresholds of mechanical stimuli, and produces excessive local bone appositions in entheses (Jacques et al., 2014; McGonagle et al., 2009; Schett et al., 2017). Although cortical erosions can be seen after entheseal inflammation, the most common outcome is new bone formation (Schett et al., 2017). The new Coimbra method records this EC as bone formation (Henderson et al., 2016). Other recording methods recognize this feature as enthesophytes (Crubézy, 1988; Mariotti et al., 2007a; Villotte, 2006), osteophytic formation (Mariotti et al., 2004, 2007b), ossification exostosis (Hawkey & Merbs, 1995), or proliferative lesions (Henderson, 2009).

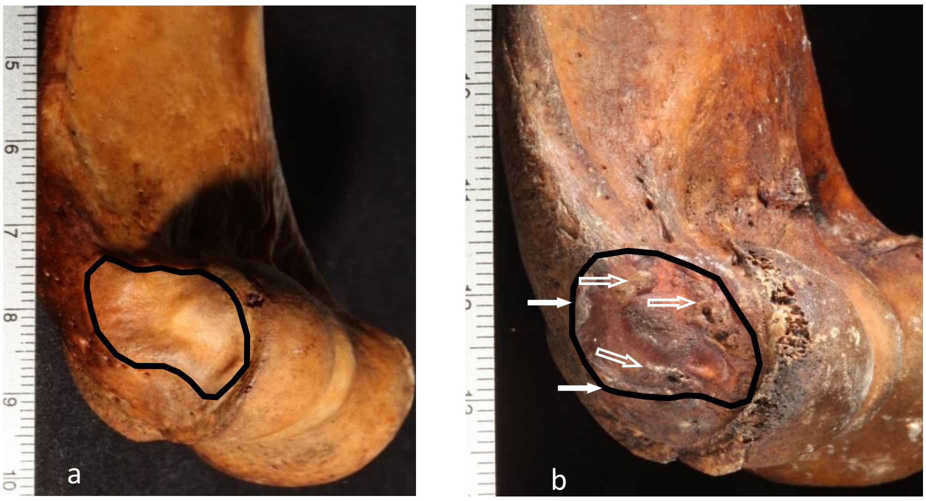


Figure 1-5. Black outline marks the extension of the entheseal surface. a. Common extensor origin with no entheseal changes. b. Common extensor origin with bone formation in zone 1 (filled arrows) and bone formation in zone 2 (unfilled arrows).

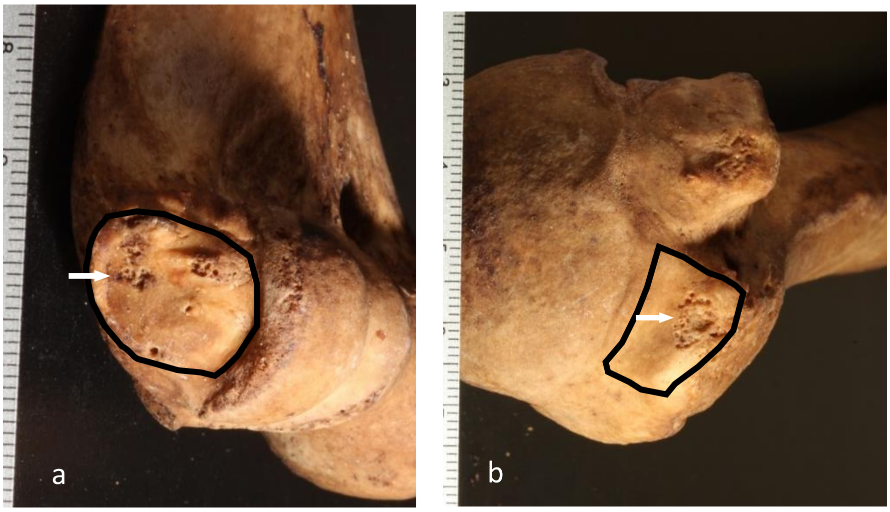


Figure 1-6. Black outline marks the extension of the entheseal surface. a. Common extensor origin with presence of erosion in zone 2. b. Supraspinatus with erosion in zone 2.

Figure 1-7. Black outline marks the extension of the entheseal surface. Iliopsoas insertion with textural change

1.4.2.1.1.2. Textural Change

Textural change is a diffuse granular texture, that can feel roughened to the touch (Henderson et al., 2016; Villotte et al., 2016) (Figure 1-7). Radial and ischial tuberosities are the entheses with the highest frequency of textural change (Villotte et al., 2016). The etiology of this feature remains unexplained. Both fine porosity and textural change are more common in young individuals, leading to the suggestion that their etiology could be linked to developmental processes (Henderson, Mariotti, et al., 2017). Villotte et al. (2016) proposed that textural change can be related to the mineralization of the uncalcified fibrocartilage. Wilczak et al. (2019) suggested that textural change could be associated with calcifications near the enthesis, or cortical irregularities observed by sonographers. Cortical irregularities are defined as “loss of regular bone contour without clear sign of enthesophyte and/or erosion” (Terslev et al., 2014). Rheumatologists have reported cortical irregularities as an early sign of SpA, and triggered by mechanical stress or low-energy trauma (Jacques & McGonagle, 2014; Kaeley, 2020; McGonagle, Marzo-Ortega, O’Connor, Gibbon, Hawkey, et al., 2002).

1.4.2.1.2. Surface discontinuity

1.4.2.1.2.1. Erosions

Erosions in the entheseal surface are lesions that are wider than they are deep, and have irregular margins (Henderson et al., 2016) (Figure 1-6). Wilczak et al. (2019) suggested that bone erosions are structural damages associated with both calcifying tendinitis near the entheseal surface (Nogueira-Barbosa et al., 2015), and erosions of cortical bone (Sansone et al., 2016). Calcifying tendinitis consists of deposits of calcium phosphate crystals, mainly located near or at the insertion of the *subscapularis* tendon (Sansone et al., 2016). Although the etiology of these calcifications is not fully understood, they are associated with failures in the cell-mediated healing process linked to overload or microinjuries (Sansone et al., 2018), and poor blood supply (Gosens & Hofstee, 2009; Rothman & Parke, 1965; Sansone et al., 2016). The *supraspinatus* and *infraspinatus* tendon insertions are hypovascularized zones that have been previously recognized as being prone to degenerative lesions (Rothman & Parke, 1965). Poor blood supply has also been linked to the prevalence of calcifications in the *supraspinatus* enthesis (Gosens & Hofstee, 2009). Most calcifications detected *in vivo* patients will not be visible in the dry bone because only a small portion of these calcifications are in contact with bone tissue, with a prevalence of 5% in patients experiencing shoulder pain

(Nogueira-Barbosa et al., 2015), and up to 44% in patients with persistent lesions that require arthroscopic surgery (Porcellini et al., 2009). All calcifications that were in contact with bone tissue were associated with cortical erosions (Nogueira-Barbosa et al., 2015; Porcellini et al., 2009). Risk of calcifications increase with higher BMI and older ages (Sansone et al., 2016). Erosions can also be associated with compression forces in entheses in the lower limbs (McGonagle et al., 2008), compression associated with contusions or fractures, or following bone marrow edema in early stages of enthesitis (Hayter et al., 2013; McQueen et al., 1999).

1.4.2.1.2.2. Porosity

Fine porosity is defined in the new Coimbra method as “small, round to oval perforations with smooth, rounded margins <1mm”, that are not located in the base of an erosion (Henderson et al., 2016:926) (Figure 1-8a). Their etiology is linked to blood vessels passing from soft tissue to bone, and vice versa, using previously formed micropores (Benjamin et al., 2007; Henderson, Mariotti, et al., 2017; Villotte et al., 2016; Wilczak et al., 2019). Micropores in fibrocartilaginous enthesis measure between 100 to 400 µm wide, and appear to be normal physiological features promoting vessel invasion (McGonagle et al., 2009; Schett et al., 2017), allowing the initiation of a reparative response activated by inflammation (Benjamin et al., 2007; D’Agostino & Terslev, 2016). However, it remains unclear if fine porosity is related to the normal blood vessel channels or if their appearance is intensified during the vasodilatation phase. It is also not known whether the pores are temporary or permanent features.

The origin of macro-porosity is more uncertain than the origin of fine porosity (Figure 1-8a). Macro-pores are uncommon histologically and in dry bone observations (Benjamin et al., 2007; Wilczak et al., 2017). Their etiology could be also linked to hypervascularization associated with an active inflammation (Wilczak et al., 2019). Macro-pores are defined in the new Coimbra method as “small, round to oval perforations with smooth, rounded margins about 1mm or larger in size with the appearance of a channel, but the internal aspect is rarely visible” (Henderson et al., 2016:926).

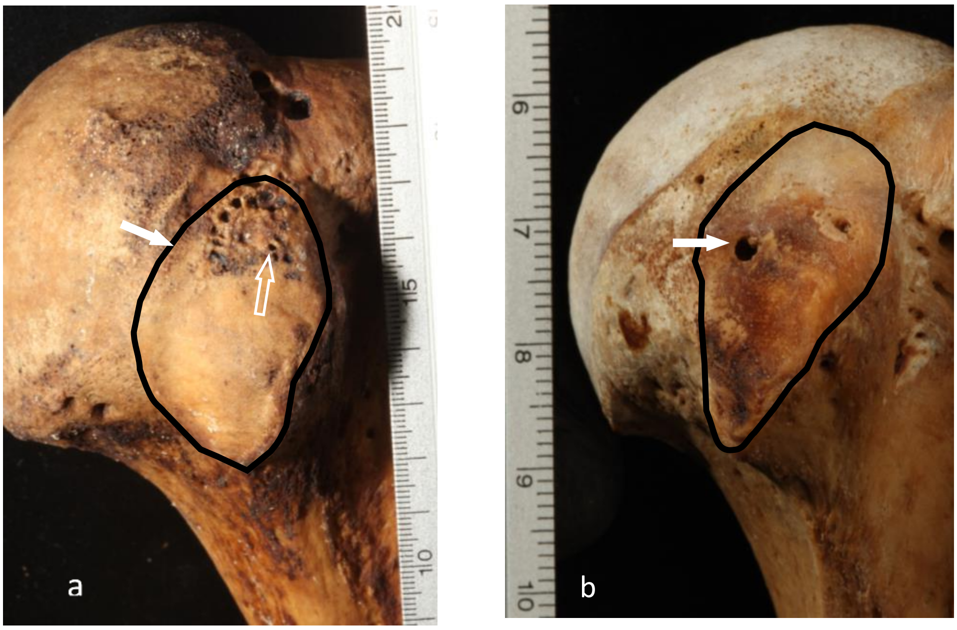


Figure 1-8. Black outline marks the extension of the entheseal surface. a. Subscapularis insertion showing fine porosity (filled arrow) and macro porosity (unfilled arrow). b. Subscapularis insertion showing cavitation.

1.4.2.1.2.3. Cavitation

Cavitation is defined by the new Coimbra method as a “subcortical cavity with a clear floor which is not a channel. The opening should be >2mm and the whole floor must be visible” (C. Y. Henderson et al., 2016:926) (Figure 1-8b). Cavitation is the most uncommon feature recorded in dry bones (Henderson, Mariotti, et al., 2017). The etiology seems related to cysts most commonly found in the rotator cuff entheses (Nogueira-Barbosa et al., 2015; Wilczak et al., 2019). In the clinical literature cysts are more frequent in older individuals and are associated with degenerative changes (Sano et al., 1998). However, the origin of the cysts appears to be different depending on the location on the greater and lesser tuberosities of the humerus. Anterior cysts are located in the *subscapularis* and *supraspinatus* entheses, are frequent in older individuals, and are associated with rotator cuff disorders such as tendinopathy, partial and full tendon tears (Fritz et al., 2007; Sano et al., 1998), but not with aging when controlling for injuries. Whereas posterior cysts near the *infraspinatus* enthesis tend to increase with aging and rotator cuff disorders, but are not significantly associated with age or injuries (Fritz et al., 2007).

In summary, the clinical literature suggests that traumatic injuries may be related to all types of ECs, except bone formation (Table 1-4). Older adults are more prone to have erosion after a traumatic event involving compression forces, such as falls or direct blows. Textural change may be due to enthesis thickening during active inflammation, and mineralization of the uncalcified cartilage that could be triggered by low-energy trauma such as twists or falls, especially in younger individuals. Porosity as an inflammatory response promotes neovascularization in injured entheses. Finally, cavitation in the *subscapularis* and *supraspinatus* entheses is associated with rotator cuff disorders, such as tears.

Table 1-4. Summary of factors related to each type of entheseal change and citations.

	Factor associated					
Feature	**Age**	**SpA**	**Trauma**	**BMI**	**Biomechanical**	**Other pathologies**
Bone formation	Henderson et al. 2017	McGonagle et al. 2009, Schett et al. 2017		Bakirci et al. 2020	Tension and compression Benjamin et al. 2000	
Erosion	Sansone et al. 2016		Compression forces - McGonagle et al. 2008	Sansone et al. 2016	Sansone et al. 2018	Calcifying tendinitis - Wilczak et al. 2019
Textural change		Inflammation -Terslev et al. 2014	Inflammation -Terslev et al. 2014	Di Matteo et al. 2020	Inflammation - Terslev et al. 2014	
Porosity		Inflammation - Benjamin et al. 2007	Inflammation - Benjamin et al. 2007		Inflammation - Benjamin et al. 2007	
Cavitation	Fritz et al. 2007		Fritz et al. 2007, Sano et al. 1998			Cyst - Henderson et al. 2017, Sano et al. 2008

2. MATERIALS AND METHODS

This chapter describes the materials used, lists the hypotheses tested, and details the procedures performed to answer the research questions, beginning with contextualization of the population of the study, continuing with the characterization of the sample, and concluding with the methodological protocol followed to record and analyze the two main osteological sets of features i.e., entheseal changes and antemortem trauma.

2.1. Materials

The two secondary objectives (see introduction) were to explore and analyze the presence of ECs within the male Colombians: to understand the prevalence of ECs in identified male Colombian individuals, and to recognize the effect of antemortem trauma on entheseal changes in the population of forensic interest in Colombia, i.e., male individuals between 18 and 35 years (see in Chapter 1). Therefore, this research was based on skeletal evidence of individuals from two modern identified skeletal collections recently assembled in Colombia by the University of Antioquia, Medellín, and the National Institute of Legal Medicine and Forensic Sciences, Bogota D.C.

The literature reviewed suggest that antemortem trauma affects bone and soft tissue in either one of two ways, or both: by injuring bone and soft tissue during the event i.e., sudden tensile forces; or, by stimulating compensatory movements that change distribution of biomechanical loads for days, weeks, or even a lifetime (see Chapter 1). Therefore, this study aims to determine whether there is a relationship between entheseal changes and antemortem trauma, and if it is proven to exist, to test the usefulness of that relationship in the personal identification process.

The hypotheses proposed in this study were intended to be tested in two different but complementary types of samples: the sample comprised of individuals from the skeletal collections, and a small sample of fresh cadavers. However, failure to achieve methodological standardization when taking radiographs prevented the fresh cadaver sample from being taken and included in the analysis (later explained in this chapter).

2.1.1. Skeletal Collections

Identified skeletal collections are highly valuable research materials that allow biological and forensic anthropologists to adjust methods developed in foreign populations, or create new methods targeting the forensic population and specific needs of each country (Cunha et al., 2018; Ferreira et al., 2014; Petaros et al., 2021). Colombia has two modern identified skeletal collections that stand out in the South American context, because they are composed of at least 400 individuals each who died between 2003 and 2008, and each individual has more documented data than other skeletal collections (Cunha et al., 2018). One of the Colombian skeletal collections is in Bogota D.C., and the other is in Medellin. Both cities are located in the Andes (Figure 2-1).

Table 2-1. Demographic and administrative data available for the two identified skeletal collections

Data	Skeletal collection	
	UdeA	NILMFS
Sex	x	x
Age	x	x
Date of birth	x	x
Place of birth	x	x
Date of death	x	x
Cause of death	x	x
Occupation	x	-
Address of residency	x	-
Cemetery origin	x	-
Exhumation license	x	-
Height recorded in ID	-	x
Height from autopsy	-	x
Autopsy protocols	-	x

These two collections are composed of unclaimed and donated skeletal remains, all of which had death certificates (*certificado de defunción*), describing sex, age, and city of death. In some cases, other data such as height, occupation, cause and mechanism of death was also available (Table 2-1). The death certificate is an official document issued by the National Civil Registry agency based on the information registered in the national identity card (Registraduría Nacional del Estado Civil, 2020). The sex and age information provided by the cemeteries was verified through the analysis of standardized macroscopic skeletal features (Isaza & Monsalve, 2012). Therefore, the demographic information available in both skeletal collections is highly reliable. Both skeletal collections are comprised of only Colombian nationals, with different percentages of genetic admixtures (Monsalve & Hefner, 2016).

Genetic studies have shown that the contribution of the three main genetic ancestors are different in the modern populations of Bogota D.C and Medellin (Duque et al., 2012; Healy et al., 2017; Ossa et al., 2016; Salzano & Sans, 2014). The mean of the population of Bogota D.C (47% European, 45% Amerindian, 5% African) exhibited lower European and African ancestry and higher Amerindian contribution compared to the mean of the population of Medellin (66% European, 25% Amerindian, 9% African). The difference in the economic and historical processes of the geographical regions in Colombia are partly responsible for the high variability within the percentage of genetic admixture between cultural regions and individuals (Caicedo et al., 2019; Sandoval et al., 1993).

The differences between the genetic admixtures of both cities may impact the prevalence of genetically predisposed diseases associated with entheseal changes; for example, Medellín has a greater frequency of ankylosing spondylitis than Bogotá (Londoño et al., 2018). Bogota D.C and Medellin are the biggest receptors of internal migrants in Colombia (Cuervo et al., 2018; DANE, 2008), but most migrants come from near administrative departments where genetics admixtures follow similar patterns. Therefore, it is likely that the current genetic admixture patterns could maintain similar tendencies; i.e. Medellin receives mostly internal migrants and/or displacements from the rural surroundings of Medellin and the coffee region, which is comprised of the departments of Caldas, Risaralda, and Quindío (Castro-Escobar, 2016), while Bogota D.C receives people from Cundinamarca, Santander, Tolima, and Boyacá (Castro-Escobar, 2016; Meisel & Vega, 2007).

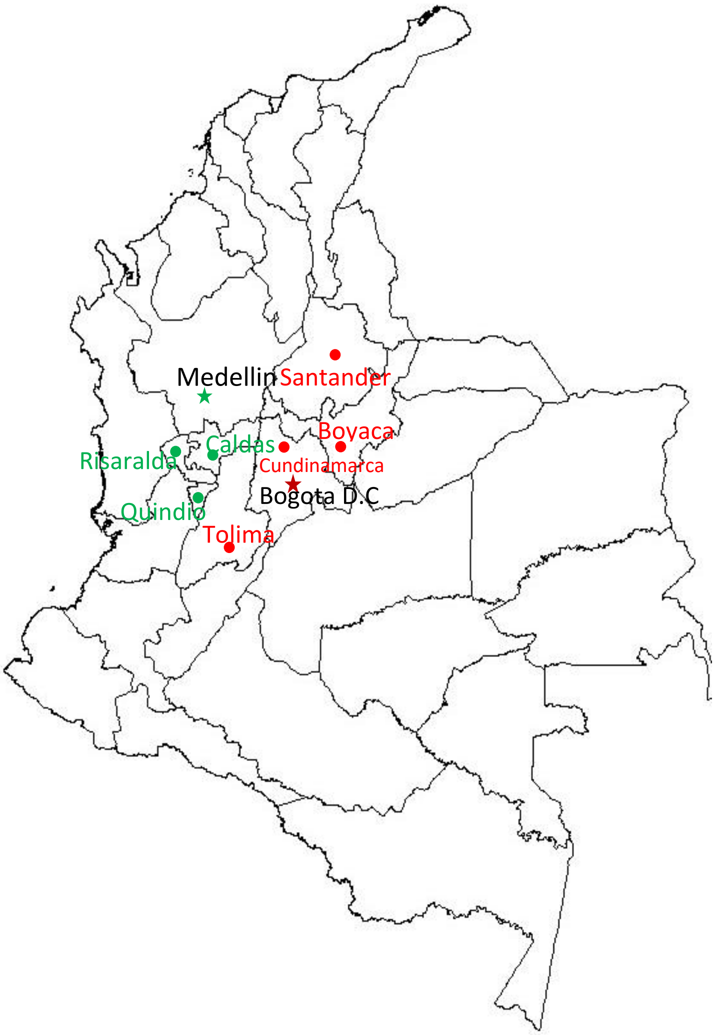


Figure 2-1. Map of Colombia locating the cities hosting the two skeletal collections, Bogotá D.C and Medellin. Red font shows origin departments of most of the internal migrants of Bogota D.C. Green font shows origin departments of most internal migrants arriving in Medellin.

Bogota D.C. is the capital city of Colombia with a population three times larger than Medellin. It is the country's primary receptor of internal migrants (Cuervo et al., 2018; DANE, 2008). Bogota D.C hosts all the institutions of the central government and was the epicenter of one of the bloodiest days in the modern history of Colombia -the 9th of April 1948, called "*El Bogotazo"* when Jorge Eliecer Gaitán, presidential candidate and leader of the Liberal party, was killed during a public speech, causing massive riots in Bogota and other major cities. *El Bogotazo* resulted in thousands of deaths, destruction, and fueled the great wave of bipartisan violence that would sweep across the country for the next decades (Bailey, 1967; G. Guzmán et al., 1962). Nevertheless, the city has been on the periphery of the social and political phenomenon denominated by The Violence – *La Violencia* (Bailey, 1967; G. Guzmán et al., 1962). Moreover, the violence surrounding drug-trafficking since the 1980's generally emanated from the headquarters of the two main drug Cartels, the Medellin Cartel led by Pablo Escobar, and the Cali Cartel of the Rodríguez-Orejuela brothers (Franco et al., 2012; Gutiérrez et al., 2013). As such, Bogota D.C has maintained homicide rates below the national average with the exception of a short period between 1992 and 1996 (Gutiérrez et al., 2013). Furthermore, Bogota D.C has enjoyed significant economic growth over the last centuries that has improved quality of life and reduced inequality, as reflected in the increased average height of individuals and reduction of height difference between male and females observed in the earliest decades of the 20th Century (Meisel & Vega, 2007).

Bogota D.C and Medellín are the two most populated cities in Colombia where social inequality increases street crimes (Franco et al., 2006; Giménez-Santana et al., 2018; Observatorio Electoral Urbano & Instituto de Estudios Urbanos (IEU), 2015). However, Medellín has been greatly impacted by drug-violence and the armed conflict since the 1980's and was the city with the highest homicide rate from 1980 to 2000, (Franco et al., 2012) making it one of the most dangerous cities in the world (Drummond et al., 2012). Homicide rates fell in Medellín from 1991 to 1998, partially due to the killing of Pablo Escobar in 1993 and disappearance of the *Cartel de Medellín.* However, the homicide rates increased again from 1998 until 2002 targeting young adults of the poorest neighborhoods of the city (Drummond et al., 2012; Gutiérrez et al., 2013). In 2003 the homicide rates decreased to close to the national average until 2008 (Franco et al., 2012). The individuals comprising the UdeA skeletal collection died between 2003 and 2005, coinciding with the years of the lowest homicide rates. Although other factors have to be considered, the generalized violence in Medellín has negatively impacted the economy and the quality of life, which in turn, has delayed or deaccelerated biological development of infants and teenagers (Meisel & Vega, 2007; Villamor et al., 2009).

2.1.1.1. *Identified skeletal collection of the University of Antioquia –UdeA*

The 613 individuals in the “Osteological Reference Collection” of the UdeA, Medellin, ranged from neonates to 99 years old, who died between 2003 and 2005 and were buried either in the *Jardín Cementerio Universal* –Universal Garden Cemetery or the *San Pedro Cementerio Museo* –San Pedro Cemetery Museum (Isaza & Monsalve, 2012). The socio-economic background of the people buried in the two cemeteries differ from one another, mainly because the Universal Garden Cemetery belongs to the city government and receives people subsidized by them (Rendón Correa, 2015), whereas the San Pedro cemetery is a private organization that charges for their mortuary services and does not bury unidentified corpses or those without financial means to cover the burial expenses (see below). The records of the specimens from the UdeA skeletal collection include age, sex, date and place of birth, date of death, cause of death, last known occupation, and last known address of residency (Table 2-1). These records also specify which cemetery the individual came from and contains administrative information such as date and number of the burial permit, and the exhumation license. The individuals of the UdeA skeletal collection were accepted by the curator when most of the bones were complete and well preserved (T. Monsalve, personal communication, March 2015). The last known occupation of the individuals from the UdeA skeletal collection were obtained from the burial permit, which is filled in by an employee of the National Civil Registry based on the information provided by the family. No standardization or protocol is followed by the Registration Office.

San Pedro Cemetery Museum was established in 1842 as the first private cemetery in Medellin by elite members of the city. Nowadays, this cemetery rents out vaults for 4 years. If relatives fail to claim the human remains by the end of this period individuals are either cremated or buried in a common ossuary (*Cementerio Museo San Pedro*, 2020). The skeletal collection consists of individuals who were to be disposed of in one of these two manners but were instead requested by the curator of the collection. This fact impacts the socio-economic class of the collection, because while individuals buried in this cemetery generally belong to a higher socio-economic class than the Universal Garden Cemetery, the families of the individuals sent to the skeletal collection usually lack the financial means to continue paying the rental fees or to buy their own vault (T. Monsalve, personal communication, March 2015).

The Universal Garden Cemetery was created in 1933 by the municipality of Medellin to remove socio-economical divisions in death and create a “universal” place to bury all citizens, including those excluded from Catholic cemeteries such as atheists, suicide cases, and liberals. However, this purpose was never fulfilled and therefore it was always known as the “cemetery of the poor” (Rendón Correa, 2015). Nowadays, the cemetery includes victims of the internal conflict, unidentified corpses, and vulnerable members of the population, i.e., people displaced by violence, abandoned children, the homeless, low-income elderly, low-income people with disabilities and/or functional impairments. Most of the unidentified corpses are victims of the internal conflict and the drug violence (EAFIT & Medialab, 2018). The unidentified corpses are a section of the UdeA skeletal collection that is intended only for teaching and not for research. None of the unidentified individuals were used in this research.

2.1.1.2. *National Institute of Legal Medicine and Forensic Sciences – NILMFS*

“The Human Skeletal Reference Collection of the Modern Colombian Population” in the NILMFS, Bogota DC, currently comprises of 597 individuals born between 1940 and 1987, and who died between 2005 and 2008. All skeletons are unclaimed individuals who were donated by the district administration after the fourth year of compulsory and subsidized burial (Sanabria Medina et al., 2016). The database of the NILMFS skeletal collection includes age, sex, date and place of birth, date of death, height recorded in the national Colombian identification card (*cédula de ciudadanía Colombiana*), and estimation of height from the autopsy report (Table 2-1). Most individuals of the NILMFS skeletal collection died of natural causes (65.7%). Autopsy protocols of individuals with violent deaths (34.3%) are available upon request. The individuals of this collection came from four different District cemeteries of Bogota DC (Southern Cemetery, Northern Cemetery, Central Cemetery, and Serafin Park Cemetery), all of which are managed by the District government and used to bury people with limited economic resources, unidentified bodies, and homeless individuals (Sanabria Medina et al., 2016). The NILMFS skeletal collection only received skeletons of identified individuals.

2.1.1.3. *Fresh cadaver sample*

The fresh cadaver sample was relied upon to assist in the quantification of the relationship between the external dimensions of bone diaphysis (EDB), enthesophyte formation (this is the only EC observable in radiographs), and antemortem trauma. EDB, enthesophyte formation, and antemortem trauma were common variables in the skeletal and cadaver samples allowing for the analysis of the association between the three. The sample size was previously agreed upon with the NILMFS, considering that additional time and resources were required from the NILMFS for data collection of each individual. The sample was going to be composed of 50 adult males whose families voluntarily participated in the study by filling out a survey of trauma, localized pain, and activity-related antemortem data (Appendix 1) and signing informed consent forms. This sample had the advantage of being comprised of individuals whose family members provided information regarding the trauma and physical activities of the deceased, similarly to antemortem information that could be obtained from relatives of complex and skeletonized forensic cases e.g., muscle trauma, traumatic events, localized pain, leisure activities, and means of transportation.

The high number of autopsies that must be performed daily at the NILMFS, while the relatives of the deceased are waiting for the corpses of their loved ones, requires that cases must be processed within 24 hours. The main limitation of that time frame was that almost all the fresh cadavers available in the autopsy room were at the *rigor mortis* stage, making it impossible to place the upper and lower limbs in a standardized position to take biplanar x-rays with the technology available at the NILMFS. After sampling the first two individuals, the methodology proposed in the initial project was reviewed and analyzed with the technicians of the radiology unit at the NILMFS and the only real solution was to break the *rigor mortis* by doing small incisions over specific points in the muscles, but this solution was not an option for this study because this is an intrusive technique and a permit had not been previously obtained. Given that no feasible solutions to the standardization problem were found, the fresh cadaver part of the study could not be implemented. A pilot questionnaire was collected from only one family before the decision to not include fresh cadavers was taken. The questionnaire was left out of this research.

2.1.2. Restrictions and limitations

The individuals of the two skeletal collections were well preserved and skeletons were complete, allowing for observation of skeletal signs of antemortem trauma in the appendicular skeleton and skull. Likewise, all the entheses under study were observable in almost all the individuals sampled. The major limitation of the study was the lack of medical history and antemortem information about the injuries and occupations performed by the individuals in their lives, or at least during their last years. The lack of this information restricted the type of antemortem lesions that could be included, i.e., soft tissue injuries were excluded. Therefore, this analysis focuses only on the relationship between ECs and antemortem injuries affecting the bone tissue, these were healed fractures and MO.

Timing antemortem injuries based on the skeletal evidence is limited to the process of healing (de Boer et al., 2015), and once the process is complete, which takes approximately two years, it is impossible to time the antemortem injury. On the other hand, the timing of ECs is completely unknown. Sonographers have initially classified the lesions observed in the enthesis as either active inflammatory or structural damage (Terslev et al., 2014), where inflammatory lesions are, at times, reversible (De Miguel et al., 2011; Kaeley, 2020). Not being able to accurately identify the time when ECs occur, or the age of the individual at the time of injury, makes it difficult to understand the relationship between ECs and antemortem injuries based solely in a cross-sectional study using dry bone material as in this study. However, patterns of EC presence associated with an antemortem trauma could help to resolve whether injuries leave more markers in the skeleton than the traditional indicators.

The fresh cadaver sample was designed to fill the lack of detailed antemortem records regarding physical activity, localized pain, and injuries of the last years of life. However, the technology available in the autopsy room and the internal protocols of the National Institute of Legal Medicine did not allow for the required standardization.

2.2. Methods

This section describes the methods used to sample individuals with biological profiles that most closely resemble the population of forensic interest in Colombia, as well as the methods used to record macroscopic skeletal features consistent with antemortem trauma and the different types of entheseal changes observed in fibrocartilaginous enthesis. Finally, the statistical analysis was outlined. The measurement of both the intra and inter observer error were detailed as knowing the repeatability of the method is essential for the admissibility of the forensic evidence.

2.2.1. Sample

Inclusion criteria were slightly different between the two collections due to differences in the antemortem information available in each database and the requirements that came out during the data collection. The data of the UdeA skeletal collection were collected before those from the NILMFS collection. The individuals with known occupations in the UdeA collection were prioritized over those individuals registered as "unemployed" or with "no data". After completing the sample from the UdeA collection, it was evident that some age ranges were under-represented. For this reason, age was the main factor taken into account when selecting the sample of the NILMFS skeletal collection.

2.2.1.1. *Sex and age*

As described the age range for inclusion in the sample was set between 20 and 65 years old, to focus on young individuals that is the age cohort most needing forensic anthropological evaluation in Colombia. The maximum age was set at 65 years to include a wide age range. This age limit was set as this is the official retirement age in Colombia, even though it does not include the oldest in society (the life expectancy of Colombia in 2016 was 73 years) (DANE, 2007). It should be noted that retirement does not necessarily mean that an individual stopped working or stopped performing physical activities, but some occupations are more prone to antemortem injuries than others (see below) are, therefore, it must be a factor to be considered in the analysis. Moreover, after individuals are retired the records do not provide further information regarding the main physical activity. Aging is known to be a predisposition factor for some types of EC, which makes it essential to control for age in the analysis of ECs (Henderson, Mariotti, et al., 2017). Furthermore, both immature entheses and bones change their microanatomy until the maturation process is complete (Schaefer et al., 2009; Tatara et al., 2014; Thomopoulos et al., 2007). Some entheses are located near the metaphysis zone, such as the rotator cuff insertions, and that the incomplete fusion of epiphyses can make it difficult to observe the entire entheseal surface (Henderson, Mariotti, et al., 2017). Therefore, all individuals analyzed must show a minimum of bone maturation that is commonly reached at 20 years (Falys & Lewis, 2011).

The skeletal sample consist of identified individuals born between 1940 and 1988, who died between 1940 and 1988. Therefore, age and sex are recorded in the birth certificate of each individual. Individuals were grouped into wide standardized age ranges recommended for the osteological analysis of incomplete remains (Falys & Lewis, 2011): Young adult (20-35 years), Middle adult (36-50 years), Old adult (51-65 years). All age ranges are represented in the final sample (Table 2-2).

Table 2-2. Distribution of the sample by age range

	UdeA		INMLCF		Total	
Age range	n	%	n	%	n	%
20-35	35	50.7%	34	33.3%	69	40.4%
36-50	20	29%	36	35.3%	56	32.7%
51-65	14	20.3%	32	31.4%	46	26.9%
Total	69		102		171	

Databases of both skeletal collections were used to select male individuals. Curators of both collections, and their teams, reviewed all individuals to assure that antemortem information of the records is consistent with skeletal evidence. Cases that were highlighted by them because had some inconsistency between the records and the skeleton were excluded from the sample.

2.2.1.2. Occupation

Considering that the aim of this research is to determine the relationship between trauma and entheseal changes, the occupations of the individuals included in the sample were rated according to the Colombian incidence report of non-fatal occupational injuries (Table 2-4). It is a database compiled by the Ministry of Health and Social Protection of Colombia – *Ministerio de Salud y Protección social*, that aims to *"follow up and monitor the health and work conditions of the working population affiliated to the General System of Occupational Risks"* (Ministerio de Salud y Protección Social, 2020). This database quantifies the risk of injuries by occupation according to the frequency and severity of the non-fatal injuries reported by the health insurance companies. However, the database only includes the injuries suffered in the formal labor market. The percentage of formal employees is lower than the informal labor market in Medellin -ranging from 57% to 60% informal employees during 2000-2005 (García Cruz, 2008), which were the last years of life of the individuals of the UdeA skeletal collection. This high rate of informal labor results in numerous occupational injuries being treated by the public hospitals as common injuries (Ocampo & Garzón, 2016), affecting the calculations of risk by each occupation.

All occupations are subject to some level of risk, whereby the median incidence rate of non-fatal injuries was used to separate high risk occupations (19 individuals) from low-risk occupations (29 individuals). Individuals listed as "unemployed" (7), "no data" (13), and "retired" (1) were excluded from this categorization due to the lack of knowledge of primary economic activity. The individual listed as "outlaw militia soldier" was given the same incidence rate as the "farmer" because most of the soldiers are peasants with little or no formal education who were previously involved in farming activities (O. L. Valencia & Daza, 2010) and there is no official data for the "occupation" of "outlaw militia soldier". A total of 48 individuals, from 20 different occupations were included in the study.

Table 2-3. Occupations reported for 48 individuals of the UdeA skeletal collection and rated according to the Colombian incidence of non-fatal occupational injuries. All occupations were divided into high and low risk categories.

High risk occupations				Low risk occupations			
Occupation	n	%	Colombian incidence rate	Occupation	n	%	Colombian incidence rate
Farmer	2	4%	8.18	Car washer	1	2%	3.99
Casual worker	6	13%	7.03	Employee	4	8%	3.99
Construction	2	4%	7.03	Freelance	7	15%	3.99
Baker	1	2%	6.86	Security guard	1	2%	3.99
Clothing manufacturer	1	2%	6.86	Street vendor	5	10%	3.99
Mechanic	1	2%	6.86	Watchman	4	8%	3.99
Tinsmith	1	2%	6.86	Clown	1	2%	1.91
Woodworker	1	2%	6.86	Student	5	10%	1.91
Waiter	1	2%	6.37	Recycler	1	2%	1.59
Merchant	3	6%	4.39				
Total	19	39.6%		Total	29	60.4%	

Percentage of each occupation was calculated considering only the 48 individuals with known occupation.

2.2.1.3. Inclusion criteria

Several studies have demonstrated that bone forming diseases such as seronegative spondyloarthropathies (SpA), and diffuse idiopathic skeletal hyperostosis (DISH), have a direct effect in the entheses causing pathological inflammation, which in turn stimulates generalized presence of new bone formation (Benjamin & McGonagle, 2001; Cunha & Umbelino, 1995; Henderson, 2008; Nascimento et al., 2014; Schett et al., 2017). Thus, all individuals showing unilateral or bilateral sacroiliac ankylosis, ossification of spinal ligament involving more than two vertebrae, or generalized enthesophytes formation at more than one enthesis (Henderson, 2008) were excluded from the final sample.

Individuals that met all the following criteria were included in the skeletal sample:

- Male individuals between 20 and 65 years old.
- No signs of sacro-iliac joint fusion, vertebral body fusion, apophyseal ankylosis, or any other sign associated with a bone forming disease such as seronegative spondyloarthropathies or DISH.

- No evidence of trauma or pathologies that altered the normal morphology of the sites that are under analysis.

At the time the individuals were sampled, from February to May 2015, the two skeletal collections combined totals 1067 individuals, 363 of whom were male individuals between 20 and 65 years old. However, the sample had to meet the described criteria to fulfill the biological and methodological requirements of this study. The final sample size, after exclusions, was 171 individuals (Table 2-3).

Table 2-4. Total individuals included in the sample.

Laboratory	**Institution**	**City**	**Cemetery origin**	**Male individuals between 20-65 years in the collection**	**Individuals included**	**Percentage of total sample**
Forensic Anthropology	NILMFS	Bogota D.C	NA	256	102	59.65%
Osteology and Forensic anthropology	UdeA	Medellin	Universal Cemetery	15	10	5.85%
			San Pedro Cemetery	92	59	34.50%
TOTAL				363	171	100%

2.2.2. Antemortem trauma

The skeletal features that may indicate antemortem trauma were assessed macroscopically and following the Scientific Working Group for Forensic Anthropology (SWGANTH) protocol for trauma analysis (2011) (see Chapter 1). Myositis ossificans are not listed by the SWGANTH. However, the clinical literature supports that in 60%-75% of the cases, myositis ossificans have a traumatic origin (Best, 1997; Parikh et al., 2002). The cases with no traumatic history or congenital origin are rare and accompanied by other osteological signs that start early in childhood. These individuals show congenital malformation and may die prematurely (Rodríguez-Martín, 2006).

The appendicular skeleton and skull of all individuals were observed. Presence or absence of the following skeletal indicators of antemortem trauma were recorded. Bone and side of each indicator were registered when found to be present.

2.2.2.1. *Evidence of healing or healed fracture.*

According to the timing of healing phases, the callus calcification begins after the third week; it is only after this period that the healing process is macroscopically evident. Perfect reconstruction of fractures takes between 1 and 2 years (Maat, 2008). Antemortem fractures were recorded when clear signs of reparative response were observed such as callus osseous, new bone formation, misalignments, and smooth surfaces (Cunha & Pinheiro, 2016) (Figure 2-2).

2.2.2.2. *Pseudoarthosis.*

This is a complication of the healing process of bone fractures, where a lack of fusion of the fracture fragments is observed. It can be mistaken for amputation. However, pseudoarthrosis was recorded when the distal fragment was present, and fragmented bones showed rounded ends and cupping (Rodríguez-Martín, 2006).

2.2.2.3. *Trauma-induced degenerative joint disease.*

Osteoarthrosis (OA) has a multifactorial etiology. Trauma-induced OA develops when the surfaces of the joints are not properly aligned. Mainly as a consequence of dislocations, subluxations, or direct trauma to the joint that was not appropriately treated (Rodríguez-Martín, 2006). OA was recorded using standardized skeletal traits of degenerative joint disease, i.e. bone formation, eburnation, and surface porosity (Buikstra & Ubelaker, 1994; Weiss & Jurmain, 2007). Trauma-induced OA lesions were recorded when such traits were localized and asymmetrical (Figure 2-3).

2.2.2.4. *Infectious response accompanied by fracture.*

This is a complication of fractures, characterized by abnormal bone formation around the injury. *Cloacae, sequestrum,* or *involucrum* may be present (Ortner, 2003). Infectious diseases were recorded as an independent skeletal trait, but all cases were systematized as “fractures”.

2.2.2.5. *Surgically implanted device -SID.*

All prosthetic devices were recorded. However, the devices recorded were all associated with bone fractures. Therefore, SID were systematized as “fractures”.

2.2.2.6. *Dislocations and subluxations.*

These types of lesions are evident skeletally in cases of either absence of medical treatment or limited medical treatment. Misalignment of the joint surfaces cause OA, bone formation, and secondary or false joint surfaces (Rodríguez-Martín, 2006). Dislocations were recorded when all three skeletal traits were present. Traumatic injuries without evidence of secondary joint surfaces were recorded as trauma-induced OA.

2.2.2.7. *Myositis ossificans circumscripta -MOC.*

Rounded and irregular heterotopic ossifications were reported as MOC when the lesion was localized, near or at entheses sites, and connected to the bone (Redfern & Roberts, 2019). Small bones or fragments are often absent from the skeletal inventory; therefore, separate lesions are easily lost (Figure 2-4).

Figure 2-2. Healed fracture distal epiphysis of the left tibia

Figure 2-3. Osteoarthritis in the distal epiphysis of the left femur. Articular surface showing osteophytic lipping, most visible on the medial aspect.

Figure 2-4. Myositis ossificans in the linea aspera.

Except for the “healed fracture” and the “myositis ossificans” categories, all the other categories had small samples size i.e., between 0 and 2 individuals. To analyze the effect of antemortem trauma on EC, larger sample size were required, thus data from “healed fracture,” “stress fracture,” and “secondary osteoarthritis” was pooled into the “hard tissue” category; and data from “myositis ossificans” and “dislocation” was pooled into the “soft tissue” category. Likewise, to test the physiological implications of the injuries all the skeletal evidence of antemortem trauma were pooled into body segments and limbs.

Body segments of the upper limbs:

1. Overall trauma in the upper limbs: included all individuals exhibiting skeletal evidence of antemortem trauma in at least one bone.
2. Traumatic injuries by side: this variable was subdivided into right and left side. Each anatomical side includes all individuals exhibiting skeletal evidence of antemortem trauma in at least one bone.
3. Traumatic injuries by joint complexes: this variable was subdivided into right and left side. Elbow, wrist, and hand joint complexes were pooled together to provide a larger sample size. Each anatomical side includes all individuals exhibiting skeletal evidence of antemortem trauma in at least one of the following bones:
    3.1. Shoulder: clavicle, scapula or humerus.

    3.2. Elbow/wrist/hand: humerus, radius, ulna, carpal, and metacarpal bones.

Body segments of the lower limbs:

4. Overall trauma in the lower limbs: included all individuals exhibiting skeletal evidence of antemortem trauma in at least one bone.
5. Traumatic injuries by side: this variable was subdivided into right and left side. Each anatomical side includes all individuals exhibiting skeletal evidence of antemortem trauma in at least one bone.
6. Traumatic injuries by joint complexes: this variable was subdivided into right and left side. Each anatomical side includes all individuals exhibiting skeletal evidence of antemortem trauma in at least one of the following bones.
    6.1. Hip: Ox coxae and femur.
    6.2. Knee: femur, patella, tibia, and fibula.
    6.3. Ankle/foot: tibia, fibula, tarsal, and metatarsal bones.

2.2.3. Entheses recorded

The entheses chosen for this study are associated with the major joints of the body and are involved in the main movements of limbs (Table 2-5). The study is intended to obtain results that can be compared to other studies, therefore the entheses that are more frequently reported in the literature were prioritized. Right and left side datasets were recorded as separate variables. Table 2-5 listed the entheses included, based on the above criteria.

Table 2-5. Fibrocartilaginous entheses recorded using the Coimbra method.

Bone	**Muscle/tendon/ligament/ fascia**	**Enthesis recorded**	**Main function**
Humerus	*Subscapularis*	Insertion	Medial rotation and adduction of the arm
Humerus	*Infraspinatus*	Insertion	Lateral rotation and adduction of the arm
Humerus	*Supraspinatus*	Insertion	Abduction of the arm
Humerus	Common flexor	Origin	Flexion of the forearm/adduction wrist/flexion fingers
Humerus	Common extensor	Origin	Extension of the forearm/abduction wrist/ extension fingers
Radius	*Biceps brachii*	Insertion	Flexion of the arm and forearm. Abduction of the arm
Ulna	*Triceps brachii*	Insertion	Extension of the forearm. Adduction of the arm
Femur	Iliopsoas	Insertion	Flexion and rotation of the hip
Femur	Gastrocnemius	Origin (inner head)	Plantar flexion
Patella	*Quadriceps femoris*	Insertion	Extension of the knee /flexion hip
Patella	*Vastus lateralis*	Insertion	Extension and stabilization of the knee
Tibia	Patellar ligament	Insertion	Connects the patella to the tibia, extension and stabilization of the knee
Calcaneus	*Triceps surae*	Insertion	Plantar flexion
Calcaneus	Plantar fascia	Origin	Supports the arc of the foot. Elongation during walking.

2.2.3.1. *Subscapularis –insertion*

The *subscapularis* is a large triangular-shaped muscle originating in the subscapular fossa and inserts into the lesser tuberosity of the humerus (Figure 2-5a). As part of the rotator cuff, it helps with the stabilization of the shoulder. Its main function is to rotate the arm inwards. *Subscapularis* tears are the least common injuries of the rotator cuff muscles. Isolated injuries are extremely rare and related with traumatic events (Gerber & Krushell, 1991), but *subscapularis* tears are less uncommon (8%) when the *supraspinatus* is also injured (Frankle & Cofield, 1992). This muscle is most commonly injured due to degenerative processes, while acute traumatic injuries are more frequent in young individuals, and the mechanism of injury is mostly hyperextension and external rotation of the shoulder (Lyons & Green, 2005).

2.2.3.2. *Supraspinatus –insertion*

The *supraspinatus* muscle originates in the supraspinous fossae of the scapula and inserts into the greater tuberosity of the humerus (Figure 2-5b). It is one of the four muscles of the rotator cuff. This muscle assists the external rotation and abduction of the arm (Ellis & Mahadevan, 2013) and it is likely that this muscle is the initiator of abduction motion (Wattanaprakornkul et al., 2011). The presence of the *supraspinatus* bursa helps to dissipate stress away. Injuries in the *supraspinatus* tendon are due to both overuse and trauma. The former is most reported in people over 40 who perform activities involving throwing and similar overhead motions (Green et al., 1998); the latter is observed most frequently in falls with outstretched arms and shoulder injuries. *Supraspinatus* tears in individuals younger than 40 years are rare and associated with traumatic injuries rather than overuse (Lazarides et al., 2015).

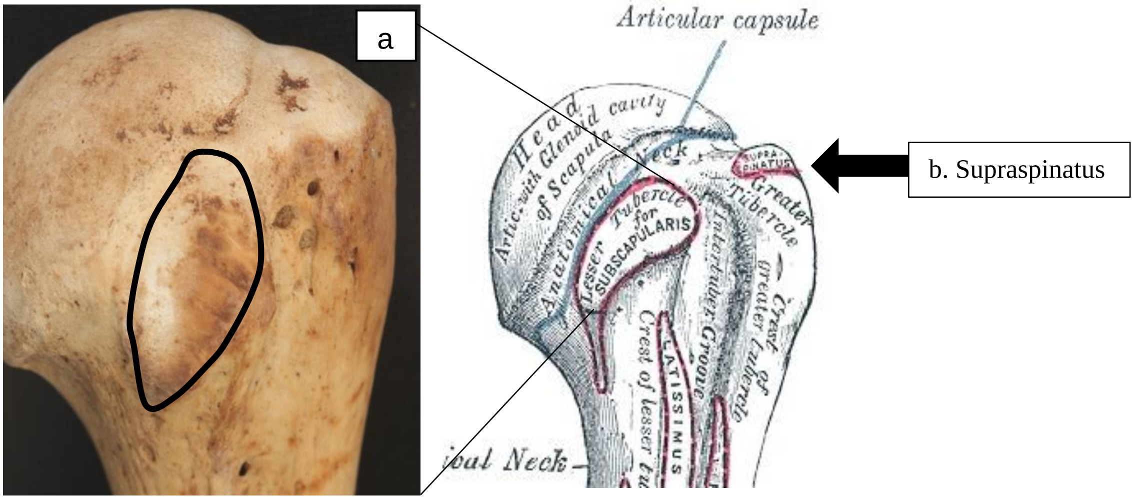


Figure 2-5. a. Subscapularis insertion enthesis, b. Supraspinatus insertion enthesis. Modified from Gray's anatomy.

2.2.3.3. *Infraspinatus –insertion*

The *infraspinatus* muscle is triangular-shaped and originates in the infraspinous fossa of the scapula and inserts into the greater tuberosity of the humerus (Figure 2-6). The *infraspinatus*, *supraspinatus*, *subscapularis*, and the teres minor comprise the rotator cuff. This muscle assists in the external rotation of the arm and the stabilization of the shoulder. Isolated tendon tears of this muscle are rare and often related to indirect trauma (R. M. Frank et al., 2017; Nové-Josserand et al., 2008).

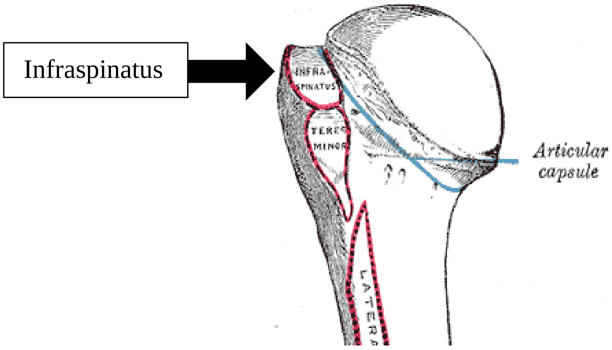


Figure 2-6. Infraspinatus insertion. Modified from Gray's Anatomy.

2.2.3.4. *Common extensor origin –origin*

The common extensor origin connects to four different muscles of the posterior aspect: the *extensor carpi radialis brevis, extensor digitorum, extensor digiti minimi*, and the *extensor carpi ulnaris*. This tendon inserts into the lateral epicondyle of the humerus (Figure 2-7a). Tears to this tendon are the most frequent injuries of the elbow and generally due to overuse or acute traumatic events (Hayter & Adler, 2012; Kachrimanis & Papadopoulou, 2010). Lateral epicondylosis, also known as "tennis elbow", is reported in over 50% of tennis players at one time or another and is oftentimes found in non-athletes between 40 and 60 years (Hayter & Adler, 2012).

2.2.3.5. *Common flexor origin–origin*

The common flexor tendon connects to the five muscles at the front of the forearm: *flexor carpi ulnaris, palmaris longus, flexor carpi radialis, pronator teres*, and the *flexor digitorum superficialis*. This tendon inserts into the medial epicondyle of the humerus (Figure 2-7b). The muscles are involved in the rotation of the forearm and bending of the wrist. They are also antagonist muscles of the muscles associated with the common extensor origin. Partial and full tears in this tendon are rare, even in athletes (Yeh et al., 2011). Golfer's elbow is an overuse injury that is five times less common than lateral epicondylosis, and it is frequently related to stress of the flexor-pronator muscle group used in activities like carpentry (McMurtrie & Watts, 2012).

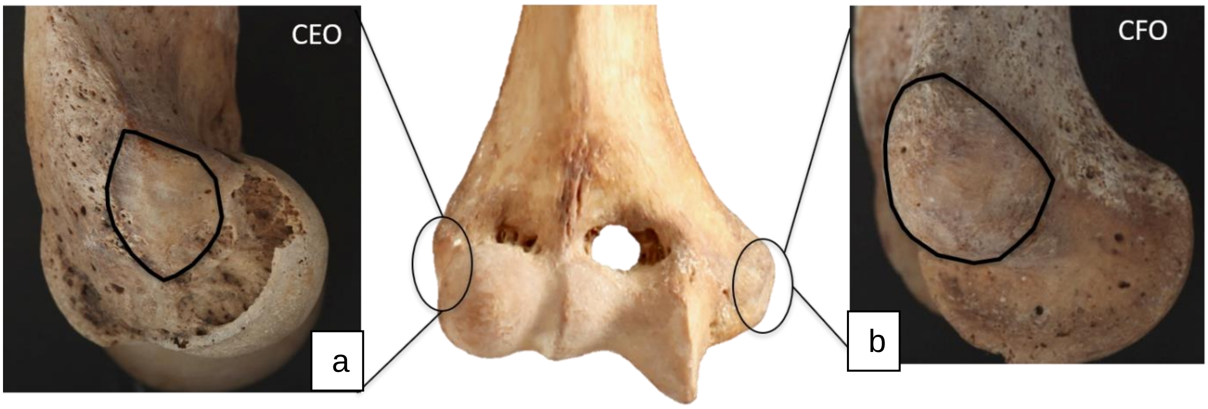


Figure 2-7. a. Common extensor origin, b. common flexor origin.

2.2.3.6. *Biceps brachii –insertion*

The *biceps brachii* muscle has two points of origin, the short (FB enthesis) and the long head (FC enthesis), both located in the scapula. It also has two insertion sites, the radial tuberosity (FC enthesis) and the bicipital aponeurosis. Only the insertion in the radius was recorded and analyzed in this research (Figure 2-8a). This is because the origin of the long head, the only other FC enthesis of the *biceps brachii* muscle, is a small and variable enthesis difficult to standardize for scoring. The *biceps brachii* muscle supinates the forearm and flexes the elbow (Bogart & Ort, 2007). Injuries in the *biceps brachii* are caused by repetitive microtrauma or sudden overexertion and are generally reported in athletes over 35 years old, and non-athletes over 65 years old (Arroyo et al., 1997). Rotator cuff tears and *biceps brachii* injuries are often associated (Hayek et al., 2015).

The *biceps brachii* insertion combines two muscle heads that appear to have distinct main functions into the same tendon. While the long head is a better supinator muscle, the short head is a better flexor muscle (Eames et al., 2007). Those muscle heads seem highly anatomically variable (Fogg et al., 2009), and most of the individuals tend to maintain their anatomical division from the origin to the insertion point. Several footprints of the insertion have been proposed, but there is consensus in that the long head inserts more proximally and the short head more distally (Athwal et al., 2007; Bhatia et al., 2017; Eames et al., 2007; Jarrett et al., 2012). The origin of the anatomical variability observed in the insertion of the *biceps brachii* remains unclear, however, they appear to be related to body size and sex (Athwal et al., 2007; Nolte & Wilczak, 2013), or population variability (Bhatia et al., 2017; Nolte & Wilczak, 2013).

2.2.3.7. *Triceps brachii –insertion*

Triceps brachii is Latin for "three-headed (muscle) of the arm", with the three points of origin of this muscle: the long, lateral, and medial heads. The long head is located in the scapula, and the lateral and medial heads are located in the humerus diaphysis. This is a large powerful muscle located on the back of the humerus and inserted in the posterior surface of the olecranon process of the ulna (Figure 2-8b). Its main function is to extend the elbow and support elbow stability. The triceps is the antagonist muscle of the *biceps brachii* and brachialis. Triceps tendon tears are rare accounting for less than 1% of all tendon injuries in the upper limbs (Blackmore et al., 2006; Rineer & Ruch, 2009), and are mostly found near the distal enthesis (Khiami et al., 2012). Lesions on these muscles are associated with pre-existing systemic conditions or drug treatments. Traumatic injuries are commonly reported in male individuals from 30-50 years old, who are involved in full contact sports (Khiami et al., 2012) and weightlifters (Sollender et al., 1998).

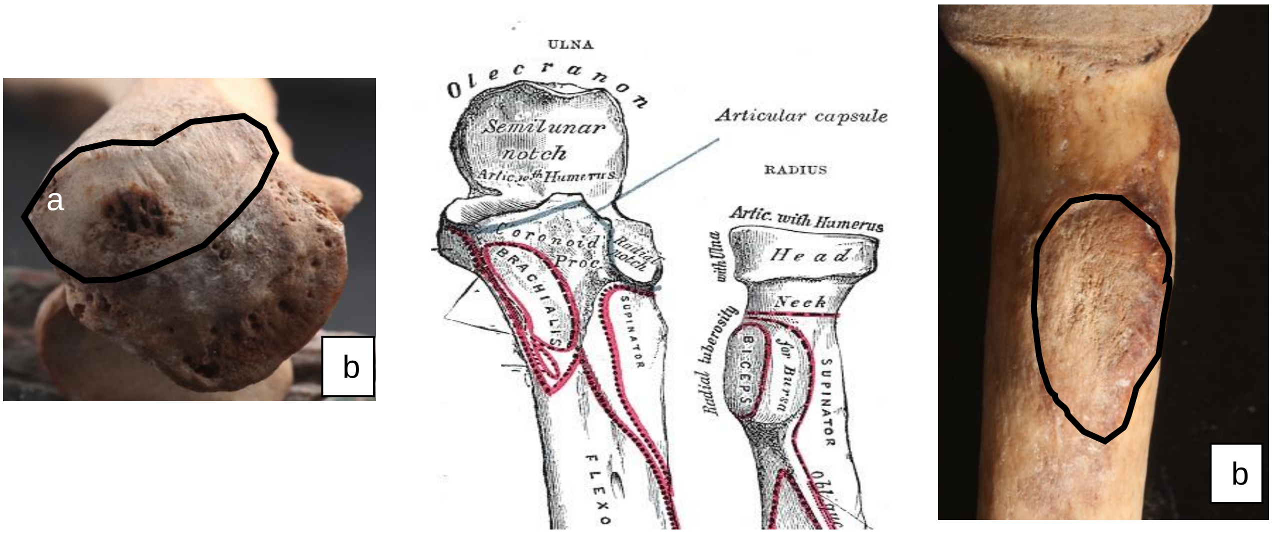


Figure 2-8. a. Triceps brachii insertion, b. biceps brachii insertion. Modified from Gray's Anatomy.

2.2.3.8. *Iliopsoas –insertion*

The iliacus and psoas muscles converge to form the iliopsoas tendon, which inserts into the lesser trochanter of the femur (Figure 2-9). The iliopsoas muscle is responsible for hip flexion. Injuries in this tendon are uncommon. Partial tears and myotendinous strains are most frequent among those younger than 65 years old, while complete tears are the most reported injury to this muscle for those over 65 years (Freire et al., 2013; Petchprapa & Bencardino, 2013).

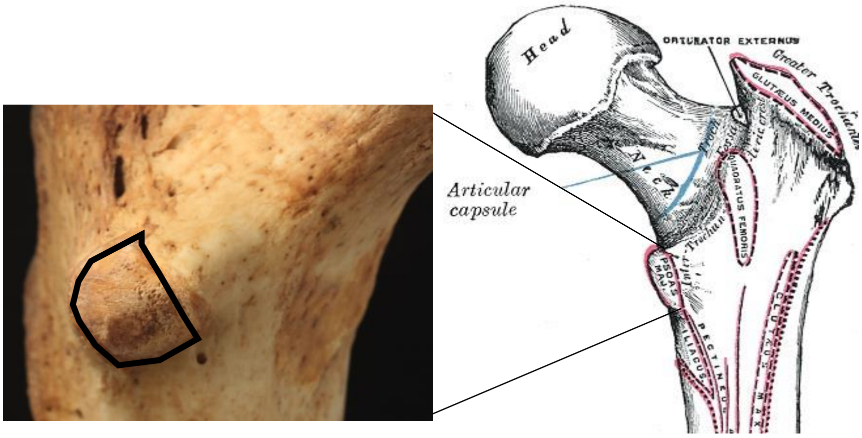


Figure 2-9. Iliopsoas enthesis. Modified from Gray's Anatomy.

2.2.3.9. *Gastrocnemius –origin*

The gastrocnemius is a two-headed muscle of the posterior aspect of the lower leg. The inner head originates from the medial condyle of the femur, while the outer head is located in the lateral condyle of the femur. Only the inner head was recorded and studied in this research (Figure 2-10). The gastrocnemius muscle is responsible for plantar flexion of the foot and flexion of the knee. Muscle injuries of the calf are common in athletes and non-athletes alike. The position and function of the gastrocnemius muscle make it prone to tears and strains. This is one of the most frequent injuries reported for tennis players (also known as “tennis leg”); soccer players (Armfield et al., 2006), and activities involving sudden movements that overstretch this muscle (Nsitem, 2013).

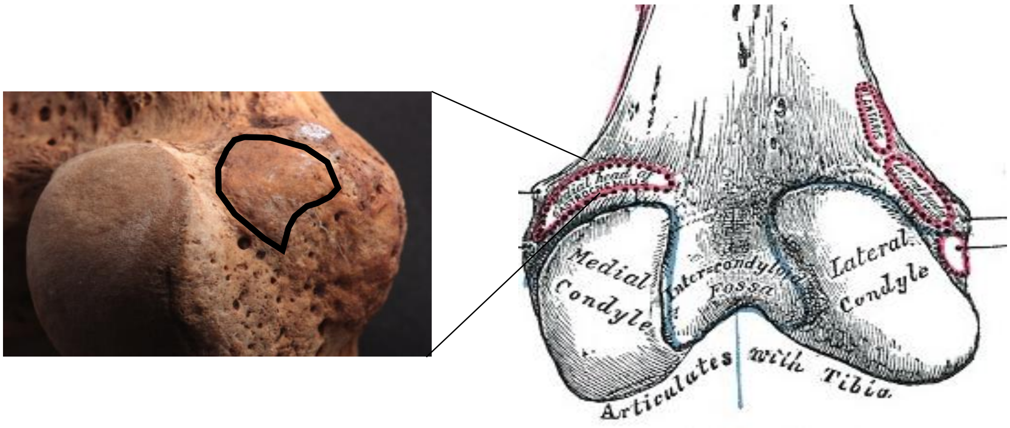


Figure 2-10. Gastrocnemius enthesis. Modified from Gray's Anatomy.

2.2.3.10. *Quadriceps femoris –insertion*

Four of the most powerful muscles of the anterior aspect of the thigh merge together to form the *quadriceps femoris* (Figure 2-11a). The rectus femoris, vastus lateralis, vastus intermedius, and vastus medialis muscles are responsible for the extension of the leg. The *quadriceps femoris* tendon inserts first in the anterior superior aspect of the patella and continues to the tibial tubercle as the patellar ligament (Waligora et al., 2009). This tendon has been described as a three-layered structure (Figure 2-12): "*rectus femoris* most superficially, *vastus medialis* and *lateralis* in the intermediate layer, and *vastus intermedius* most deeply" (Waligora et al.,

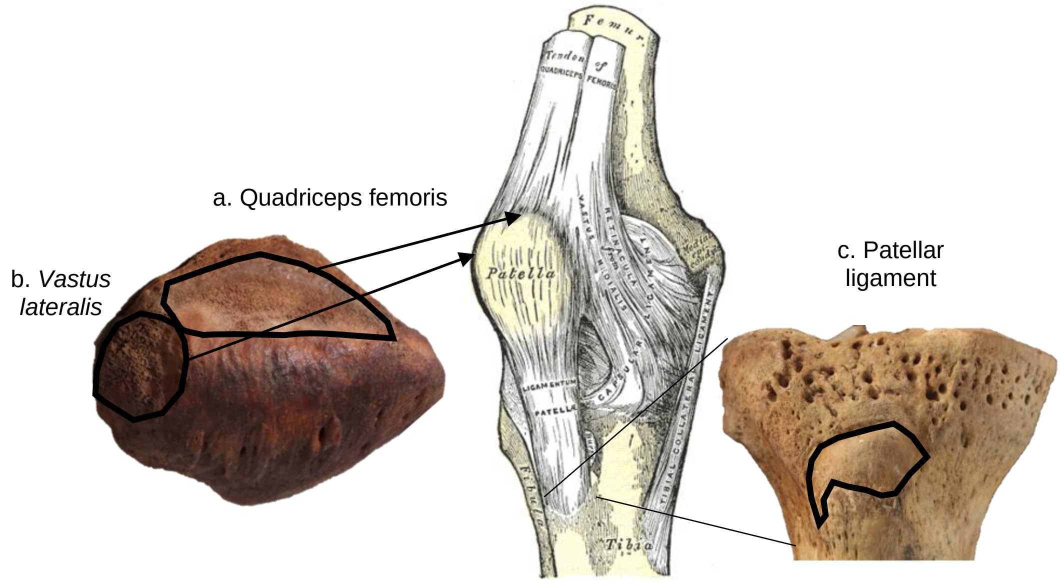


Figure 2-11. a. Quadriceps femoris insertion, b. vastus lateralis insertion, c. Patellar ligament insertion. Modified from Gray's Anatomy.

2009: 3937). However, the anatomy of this tendon appears to be highly variable. Waligora and colleagues found that only 3 out of 20 dissected patellae followed the typically described pattern, and in 60% of the cases, the oblique head of the *vastus lateralis* was separated from the longitudinal head. Bilaminar and trilaminar are the most frequent structures, but fiber arrangements vary in terms of configuration and thickness of each layer (Waligora et al., 2009; Zeiss et al., 1992). Clinical consequences of such variability are unknown, but it has been hypothesized that anatomical differences in the insertion point could affect patellar motions and stability (Waligora et al., 2009). Moreover, anatomical differences in this tendon may have an impact on the frequency and type of entheseal changes.

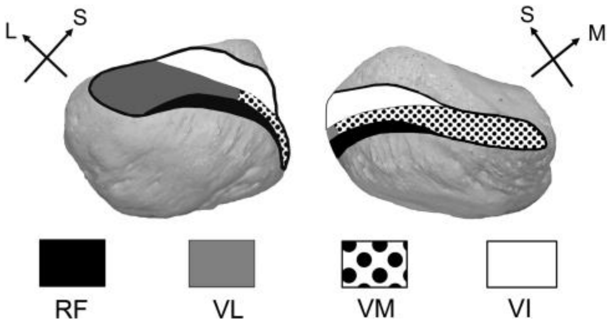


*Figure 2-12. "Approximate areas of attachment of the quadriceps tendon components onto the base and sides of the patella. RF = Rectus femoris, VL = Vastus lateralis, VM = Vastus medialis, VI = Vastus intermedius, L = Lateral, S = Superior, M = Medial" (*Taken from Waligora et al. 2009).

Injuries in the *quadriceps femoris* tendon commonly occur in male athletes between 15 to 30 years old, involved in sports that produce sudden forceful eccentric contraction of this muscle e.g., soccer, rugby, or American football players. Muscle strains and contusion in the rectus femoris are the most reported injuries to the *quadriceps femoris* tendon (Kary, 2010). Tendon tears are common in people over 40 years with predisposition factors such as renal failure and other degenerative conditions (Siwek & Rao, 1981).

2.2.3.11. *Vastus lateralis –insertion*

The vastus lateralis is the largest muscle of the *quadriceps femoris* group. This muscle has three points of origin, all located in the femur: the greater trochanter, the intertrochanteric line, and the linea aspera. It attaches to the lateral border of the patella (Figure 2-11b). The muscle's main function is to assist in knee extension and pulls the patella laterally. Isolated injuries of this tendon are extremely rare, with only a few cases reported in the literature (J. M. Frank et al., 2013; LaBore & Weiss, 2003; Phadnis et al., 2009). All reported cases involved biomechanical overuse of the knee.

2.2.3.12. *Patellar ligament –insertion*

The patellar ligament is a strong ligament that originates in the apex of the patella and inserts into the tibial tuberosity (Figure 2-11c). This ligament is a continuation of the *quadriceps femoris* tendon, inserted into the tibia via the patella, giving it the alternative name of patellar tendon. The patellar ligament connects the knee with the lower limb to form a biomechanical unit with the *quadriceps femoris*, allowing leg extension at the knee. Such motion has a primary role in walking, running, and jumping. Jumper's knee, or patellar tendinopathy, is a common overuse injury that has been reported for male athletes performing jumping sports such as basketball, volleyball, and long and high jump (Ferretti, 1986; Kulig et al., 2013; Santana & Sherman, 2020). However, the least prevalent location for jumper's knee is the insertion of the patellar ligament into the tibial tuberosity (10%) (Ferretti, 1986). Traumatic avulsion of the patellar ligament is a rare injury found in both skeletal mature and inmature individuals who are involved in sports (Major et al., 2020; Swan & Rizio, 2007).

2.2.3.13. *Triceps surae –insertion*

The *triceps surae* consists of the gastrocnemius and the soleus muscle that merge into a common tendon, the Achilles tendon, that inserts into the calcaneal tuberosity (Figure 2-13a). The Achilles tendon is the largest and most powerful tendon of the human body; it can resist tensile forces up to 10 times body weight during athletic activities (Raikin, 2014). Plantar flexion with adduction, medial rotation of the foot, and control of balance when walking are the primary functions of the Achilles tendon (Dalmau-Pastor et al., 2014). Injuries in this tendon are very common, mostly in male athletes between 20 and 39 years old, basketball causing the most injuries (Lemme et al., 2018). The prevalence of rupture of this tendon in the general population is between 5-10/100,000 (Pękala et al., 2017). People with body mass index

(BMI) higher than 25 kg/m^2 are more likely to suffer Achilles tendon rupture than those ranging between 18.5 to 25 kg/m^2 during non-athletic activities (Raikin, 2014).

2.2.3.14. *Plantar fascia – origin*

The plantar fascia, also known as the plantar aponeurosis, is a strong white fibrous tissue located in the sole of the foot, originating from the calcaneal tubercle and extending to the forefoot (Figure 2-13b). It has three components: medial, central, and lateral. The central part is the thickest and largest of the three structures, which originates in the medial apophysis of the calcaneal tuberosity and extends towards the front of the foot, where it separates into five bundles –one for each toe (D. W. Chen et al., 2014). Its main role is to stabilize the arch of the foot when walking. It had been hypothesized that plantar fascia is the continuity of the Achilles tendon. However, this connection exists in fetuses but gradually diminishes with age. Morphologically, in the mid-20s the fibers are completely absent, leaving only a connection between the paratenon and the plantar fascia (Dalmau-Pastor et al., 2014; Snow et al., 1995). *Plantar fasciitis* is considered an overuse injury associated with physical activities that have a high impact on the foot such as running (Chandler & Kibler, 1993). However, Kumai and Benjamin (2002) found that bony spurs are not located within the plantar fascia enthesis itself leading them to suggest that spurs are degenerative changes rather than traction induced changes. This is consistent with the greater presence in overweight and non-athletic individuals (Van Leeuwen et al., 2016) or individuals with genetic predisposition to spondyloathropaties (McGonagle, Marzo-Ortega, O'Connor, Gibbon, Pease, et al., 2002). Bony spurs have been

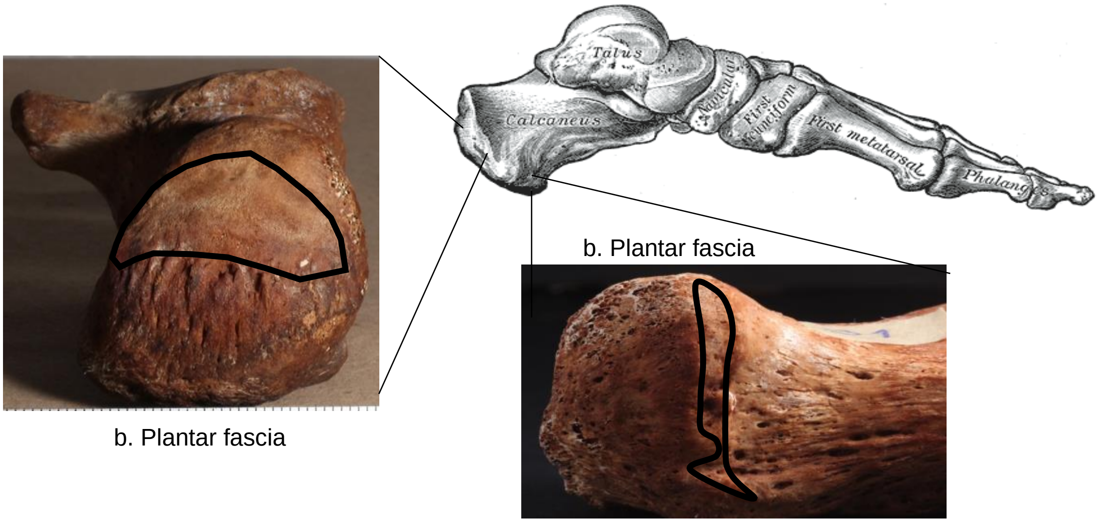


Figure 2-13. a. Triceps surae insertion, b. Plantar fascia. Modified from Gray's Anatomy.

reported in *plantar fasciitis*, but their relationship with heel pain remains unclear (Kirkpatrick et al., 2017).

2.2.4. Entheseal changes

As discussed earlier in the thesis (see Chapter 1), the complexity of factors involved in the expression of EC requires a methodology that controls for major factors that have been demonstrated to influence EC e.g., age and sex hormones (Henderson & Nikita, 2016; Jurmain et al., 2012; Michopoulou et al., 2015). Other factors, such as biomechanical loading, body size, and genetic predisposition, appear to have a more subtle role in ECs. One-off trauma associated with sudden overload has been considered to have an effect on EC, but it has not been tested on identified skeletal collections (Henderson, Mariotti, et al., 2017). In past studies, ECs in both the left and right side of the body have been reported as separate variables in order to identify bilateral asymmetries (Henderson et al., 2013). To identify biomechanical association between body segments and presence of injuries, the entheses of muscles working synergistically were pooled into joint complexes:

- Shoulder: *subscapularis, supraspinatus, infraspinatus*
- Elbow: *biceps brachii* and *triceps brachii*
- Wrist/hand: common extensor origin and common flexor origin
- Hip: iliopsoas
- Knee: *quadriceps femoris, vastus lateralis*, patellar ligament
- Ankle/foot: gastrocnemius, *triceps surae*, plantar fascia

In the upper limb these joint complexes follow the same model as previous studies (Henderson & Nikita, 2016). But no similar studies exist for the lower limbs as this part of the body has been less frequently studied (Acosta et al., 2017).

2.2.5. The new Coimbra Method –EC

Entheseal changes have been recorded in anthropology systematically, since Hawkey and Merbs (1995) published the method previously developed by Hawkey (1988). This method continues to be the most widely used as it employs visual standards and was the first published method. However, the method was developed without distinguishing between fibrous and fibrocartilaginous entheses, which causes a biological error that can result in misinterpretations of activity-patterns. Numerous other methods have been developed (Crubézy, 1988; Henderson, 2009; Mariotti et al., 2004, 2007a; Villotte, 2006). However, Mariotti et al. (2004, 2007) and Villotte (2006) stand out as they developed more descriptive and visual methods that accounted for the independent evaluation for each one of the changes. Additionally, it is important to consider the anatomical differences between fibrocartilaginous and fibrous entheses, factors that were simultaneously and independently incorporated into recording methods by Henderson and Villotte (Jurmain et al., 2012). The Mariotti and Villotte methods form the basis for the new Coimbra method that was created by a group of researchers (including Mariotti and Villotte), that aims to separately record all different types of changes in fibrocartilaginous entheseal surfaces (Henderson et al. 2013).

The entheses are complex structures that have internal anatomical variations. Considering the internal anatomy of the fibrocartilaginous entheses, the Coimbra method divides the more fibrous zone from the rest of the enthesis. Henderson and colleagues describe the two zones as: "Zone 1 is the margin of the enthesis at which the fibers attach most obliquely to the bone […] Zone 2 encompasses the remaining fibrocartilaginous footprint of the enthesis and the remaining margin. In most entheses Zone 2 is closest to the joint surface." (Henderson et al. 2016:928).

As explained before (see Chapter 1) each of the factors associated with the etiology of EC have a differential effect by enthesis and by feature. Considering the biological strength of the new Coimbra method, and the advantage of recording each feature as an independent variable, this method was chosen as the most appropriate recording protocol for the purposes of this thesis. The main limitations of the new Coimbra method are the requirement of hands-on training and prior knowledge of the normal variability of some enthesis e.g., *biceps brachii* (Wilczak et al., 2017). The method was applied in the 14 fibrocartilaginous entheses listed above in both the left and right sides of individuals from the skeletal collections. Each characteristic was recorded independently according to the scoring system created by Henderson et al. (2016) (Table 2-6). EC were recorded only when more than 50% of the enthesis surface was observable. The following recommendations were made by the developers of the new Coimbra method

(Henderson et al., 2016:928) to ensure standardized observational conditions, all of which were implemented in the fieldwork of this study:

- Identify the maximum area of the enthesis surface prior to observation.
- No additional magnification when observing the entheses. Magnification can be used for identification of post-mortem damage.
- The bone structure should be held 20-30 cm from the eye.
- Make observations under full spectrum lighting or natural daylight.
- The bone should be fully rotated to enable all aspects to be observed from different angles.
- To avoid observer fatigue, frequent breaks are recommended.

Table 2-6. Summary of the features and scores evaluated with the new Coimbra method (taken from Henderson et al., 2016:926).

Zone	Feature	Abbrev.	Definition	Degrees of expression
Zone 1	Bone Formation	BF (Z1)	See degrees of expression. Normal morphological smooth rounded or mound-like (check by touching) margins, even if the margin is elevated, should be scored as 0.	1= distinct sharp demarcated new bone formation along the margin or other enthesophyte which does not meet the criteria for stage 2 in terms of size or extent 2= distinct sharp demarcated new bone formation along the margin or other enthesophyte ≥1mm in elevation and ≥50% of margin affected by new bone formation
	Erosion	ER (Z1)	Depressions or excavations of any shape and involving discontinuity of the floor of the lesion greater in width than depth with irregular margins. Only erosions >1mm, where you can clearly see the floor, were recorded. This does not include pores (i.e. rounded margins). Score erosions if they occur on bone formation.	1= <25% of margin 2= ≥25% of margin
Zone 2	Textural change	TC	A non-smooth, diffuse granular texture (with the appearance of fine grained sandpaper)	1= covering >50% of surface
	Bone Formation	BF (Z2)	Any bone production from roughness of surface to true exostoses (e.g. distinct bone projections of any form, like bony spurs, bony nodules and amorphous bone formation).	1= distinct bone formation >1mm in size in any direction and affecting <50% of surface 2= distinct bone formation >1mm in size in any direction and affecting ≥50% of surface
	Erosion	ER (Z2)	Depressions or excavations of any shape (but not covered by the definition of macro-porosity) and involving discontinuity of the floor of the lesion greater in width than depth with irregular margins. Only erosions >2mm were recorded. MPO or FPO occurring within an erosion should not be recorded separately. Bone formation is only scored if it exceeds the height of the depression (do not score woven bone). Score erosions if they occur on bone formation.	1=<25% of surface 2= ≥25% of surface
	Fine Porosity	FPO	Small, round to oval perforations with smooth, rounded margins <1mm. These should be visible to the naked eye and be in a localised area. Do not score if they are at the base of an erosion or if they occur as part of woven bone.	1= <50% of surface 2= ≥50% of surface
	Macro-porosity	MPO	Small, round to oval perforations with smooth, rounded margins about1mm or larger in size with the appearance of a channel, but the internal aspect is rarely visible. Do not score if they are at the base of an erosion.	1= one or two pores 2= >2 pores
	Cavitation	CA	Subcortical cavity with a clear floor which is not a channel. The opening should be >2mm and the whole floor must be visible.	1= 1 cavitation 2= >1 cavitation

The new Coimbra method was recently revised and adjusted for repeatability, and therefore is currently the most appropriate method to record EC on fibrocartilaginous entheses (Henderson et al., 2016, Wilczak et al., 2017). From a forensic perspective, it is imperative to ensure that the methods used for the analysis are clearly described and tested for repeatability (Christensen & Crowder, 2009), so that all experts can evaluate the entheseal changes under the same definitions. Two published studies have tested the Coimbra method's repeatability, reaching a general percentage agreement between 77% and 81%, k=0.56 and Fleiss's Kappa=0.59 (Jorgensen et al., 2020; Wilczak et al., 2017). Several other studies have used this method to record EC (Meco, 2018; Palmer et al., 2019; Salega et al., 2017).

2.2.6. Statistical analysis

The statistical analysis was focused on the two primary objectives listed in the introduction: 1) to describe the prevalence of EC in two modern Colombian skeletal collections; and 2) to identify the association of skeletal evidence of antemortem trauma with EC presence.

2.2.6.1. *Hypotheses objective 1*

To achieve the first objective, EC in entheses of the upper and the lower limbs were recorded (see above). Anatomical separation was maintained throughout the analysis to facilitate the location of differences in the prevalence of EC, if any. The following hypotheses were tested:

Upper limbs

- Ho1= The proportions of EC present in the upper limb entheses of the male individuals from the UdeA skeletal collection are not significantly different from the proportions of EC present in the upper limb entheses of the male individuals from the NILMFS skeletal collection.

  Ha1= The proportions of EC present in the upper limb entheses of the male individuals from the UdeA skeletal collection are significantly different from the proportions of EC present in the upper limb entheses of the male individuals of the NILMFS skeletal collection.
- Ho2= The proportions of EC present in the entheses of the upper limbs of the two skeletal collections are similar to each other when age is controlled for.

  Ha2= The proportions of EC present in the entheses of the upper limbs of the two skeletal collections are different from each other when age is controlled for.

- Ho3= The proportions of bilateral asymmetries of EC presence observed in the entheses of the upper limbs of the UdeA skeletal collection are similar to those observed in the NILMFS skeletal collection.

  Ha3= The proportions of bilateral asymmetries of EC presence observed in the entheses of the upper limbs of the UdeA skeletal collection are different from those observed in the NILMFS skeletal collection.
- Ho4= The bilateral asymmetries of EC presence observed in the entheses of the upper limbs within the age ranges are similar between the two skeletal collections.

  Ha4= The bilateral asymmetries of EC presence observed in the entheses of the upper limbs within the age ranges are different between the two skeletal collections.

Lower limbs

- Ho5= The proportions of EC present in the lower limb entheses of the male individuals from the UdeA skeletal collection are not significantly different from the proportions of EC present in the lower limb entheses of the male individuals from the NILMFS skeletal collection.

  Ha5= The proportions of EC present in the lower limb entheses of the male individuals from the UdeA skeletal collection are significantly different from the proportions of EC present in the lower limb entheses of the male individuals of the NILMFS skeletal collection.
- Ho6= The proportions of EC present in the entheses of the lower limbs of the two skeletal collections are similar to each other when age is controlled for.

  Ha6= The proportions of EC present in the entheses of the lower limbs of the two skeletal collections are different from each other when age is controlled for.
- Ho7= The proportions of bilateral asymmetries of EC presence observed in the entheses of the lower limbs of the UdeA skeletal collection are similar to those observed in the NILMFS skeletal collection.

  Ha7= The proportions of bilateral asymmetries of EC presence observed in the entheses of the lower limbs of the UdeA skeletal collection are different from those observed in the NILMFS skeletal collection.

- Ho8= The bilateral asymmetries of EC presence observed in the entheses of the lower limbs within the age ranges are similar between the two skeletal collections.
- Ha8= The bilateral asymmetries of EC presence observed in the entheses of the lower limbs within the age ranges are different between the two skeletal collections

2.2.6.2. Hypothesis Objective 2

The following hypothesis aimed to identify differences in the prevalence of ECs between individuals showing macroscopic skeletal signs of antemortem trauma and those who showed no macroscopic skeletal signs of trauma. Hypotheses were tested by anatomical segments.

Upper limbs

- Ho9= The trends of EC presence of the joint complexes of the upper limbs of individuals with presence of trauma are similar to the EC trends of the individuals with non-trauma.

  Ha9= The trends of EC presence of the joint complexes of the upper limbs of individuals with presence of trauma are different from the EC trends of the individuals with non-trauma.
- Ho10= The asymmetry trends of the entheses of the upper limbs of individuals with traumatic injuries are similar to the EC trends of the individuals without traumatic injuries.

  Ha10= The asymmetry trends of the entheses of the upper limbs of individuals with traumatic injuries are different from the EC trends of the individuals without traumatic injuries.
- Ho11= Individuals with skeletal evidence of antemortem trauma in the upper limbs have higher proportions of EC presence on the joint complex located on the same limb as the lesion.

  Ha11= Individuals with skeletal evidence of antemortem trauma in the upper limbs have equal or lower proportions of EC presence on the joint complex located on the same limb as the lesion.

- Ho12= Individuals with skeletal evidence of antemortem trauma in the upper limbs have higher proportions of EC presence on the joint complex located on the opposite limb as the lesion.

  Ha12= Individuals with skeletal evidence of antemortem trauma in the upper limbs have equal or lower proportions of EC presence on the joint complex located on the opposite limb as the lesion.

Lower limbs

- Ho13= The trends of EC presence of the joint complexes of the lower limbs of individuals with presence of trauma are similar to the EC trends of the individuals with non-trauma.

  Ha13= The trends of EC presence of the joint complexes of the lower limbs of individuals with presence of trauma are different from the EC trends of the individuals with non-trauma.
- Ho14= The asymmetry trends of the joint complexes of the lower limbs of individuals with presence of trauma are similar to the EC trends of the individuals with non-trauma.

  Ha14= The asymmetry trends of the joint complexes of the lower limbs of individuals with presence of trauma are different from the EC trends of the individuals with non-trauma.
- Ho15= Individuals with skeletal evidence of antemortem trauma in the lower limbs have higher proportions of EC presence on the joint complex located on the same limb as the lesion.

  Ha15= Individuals with skeletal evidence of antemortem trauma in the lower limbs have equal or lower proportions of EC presence on the joint complex located on the same limb as the lesion.
- Ho16= Individuals with skeletal evidence of antemortem trauma in the lower limbs have higher proportions of EC presence on the joint complex located on the opposite limb as the lesion.

  Ha16= Individuals with skeletal evidence of antemortem trauma in the lower limbs have equal or lower proportions of EC presence on the joint complex located on the opposite limb as the lesion.

2.2.6.3. Data

Most of the original data were recorded as categorical variables, either as dichotomous or ordinal, except for chronological age. As explained earlier in this chapter, the chronological age was grouped into three widely used age ranges “young adults” “middle adults” and “old adults”. The occupational groups were divided into “high risk” or “low risk” categories.

Antemortem trauma was assessed in terms of “presence” or “absence” and then grouped into 6 new variables, listed above, that considers the anatomical segments of both the upper and the lower limbs. Except for fractures, the sample size of all the other skeletal evidence of antemortem injuries were small, therefore all types of injuries were pooled into the same category of “trauma”, while the absence of evidence of trauma was pooled into “non-trauma”. The presence of EC in individuals from the group exhibiting “trauma” were compared to the “non-trauma” group.

Entheseal changes were separated into 8 ordinal variables (for each enthesis, as described in the new Coimbra Method). Original scores (0, 1, and 2) of the Coimbra method were used only to describe trends of each skeletal collection, but a dichotomous variable was used to simplify the interpretation of the results, therefore scores 1 and 2 were pooled into “present” category with a score of 0 representing the absence of changes (“absent”). The entheses were pooled into three joint complexes in the upper limbs and three in the lower limbs. These were shoulder, elbow and wrist/hand, and hip, knee, and ankle, respectively.

Descriptive statistics were used to characterize the age distribution of each skeletal collection and the frequencies of trauma for each age range. Frequencies of the EC were estimated for all the entheses, and all the features recorded by the Coimbra method. Frequencies of antemortem trauma per bone, per anatomical region and sides were presented.

The population variability and the socio-economic dynamics are highly divergent between Medellin and Bogota DC (discussed in the materials section); thus, the EC trends of each skeletal collection were analyzed independently and then compared between each other using Pearson’s Chi-squared when sample size were large. Variables with expected frequencies smaller than 5 were compared using Likelihood-Ratio test or Fisher’s exact test. The latter test was chosen for 2x2 contingency tables (Kim, 2017). Differences of presence of ECs with and without controlling for age were performed, as well as differences in asymmetry patterns with and without controlling for age. Generalized linear models (GLMs) with and without interaction of predictors were run using a binary logistic model (Henderson & Nikita, 2016). GLMs with small sample size could not be run due to quasi-complete separation in the data and were removed from the statistical analysis. Bonferroni correction was applied when multiple comparisons were performed (Vickerstaff et al., 2019).

Individuals from both skeletal collections were pooled together to analyze the association of antemortem trauma in the presence of EC. The presence of EC in individuals from the group exhibiting “trauma” were compared to the “non-trauma” group using Chi-squared tests. Fisher’s exact test or Likelihood-Ratio test were chosen over Pearson’s Chi-squared when test assumptions were not met (Kim, 2017). Cramer’s V or Phi coefficients were used to measure the strength of association when Chi-Squared or Fisher’s exact test results were significant (Tomczak & Tomczak, 2014). Cohen’s (2013) general guidelines were used to interpret the effect size values, where 0.2 are small, 0.3 are medium, and 0.5 are large effect sizes. Results with p-value ≤0.05 were considered statistically significant. The statistical analysis was performed using GNU PSPP software version 1.4.1.

2.2.6.4. Intra and Inter-observer repeatability

A randomly selected subset of 20% of individuals from both the NILMFS skeletal collection sample and UdeA skeletal collection was used to calculate the inter and intra observer errors.
Specialized training in the method and general professional experience can affect the results of qualitative methods in skeletal remains (Wilczak et al., 2017). The new Coimbra method was originally published in 2013 (Henderson et al. 2013), a revised version was available in 2015 (Henderson et al. 2016) and updated commentary was presented in 2017 (Henderson et al. 2017). The developers of the new Coimbra method have endeavored to constantly review and adjust the features under analysis, as well as the descriptions for each score (Henderson et al. 2016; Wilczak et al. 2017). Nevertheless, the subjectivity associated with all qualitative

methods, along with the uniqueness of the traits to be observed and their small size, increases the complexity of applying this method.

Records of two professionals with training in osteology and knowledge of the Coimbra method, Edgar Bernal (EB) and Charlotte Henderson (CH), helped to calculate Inter-observer repeatability against the observations of the present author, Maria Acosta (MA). Two subsets were obtained and analyzed independently: the CH vs MA observations which were assessed using 18 individuals randomly chosen from the XXI Century Skeletal Collection, housed at the University of Coimbra (XXIUC), and the EB vs MA observations assessed the collection of the NILMFS (Table 2-7).The XXIUC has an average age of 81.8 years old for female individuals and 71.1 years old for male individuals (Ferreira et al., 2014). These individuals were exclusively recorded for training and for testing inter-observer repeatability, thus individuals with bone former diseases were not excluded. Given the age of individuals and possible evidence of bone former diseases, it was expected that most individuals evidenced high variability in all the eight features recorded. EB and MA recorded data of twenty individuals, also randomly chosen, from the NILMFS skeletal collection. All twenty individuals were initially sampled by MA, and they all met the requirements for inclusion (see chapter 2). The subset for inter-observer repeatability testing had a mean age of 46 (SD 13.7), and skeletons showing any signs of bone former diseases were excluded. In general, these individuals showed lower variability in all features than the individuals from the XXIUC.

Scores of 1 and 2 were pooled into presence for each feature. All entheses were pooled to enable the repeatability for scoring each feature to be calculated, thus these were not calculated by enthesis. A second test was done to compare the repeatability by enthesis, for this the scores for all features were pooled. The contingency tables showed disagreements in the missing data; therefore, the category “non-observable” was included in the inter-observer analysis. A total of three categories were used to calculate Inter-observer repeatability.

Table 2-7. Summary of the samples taken to measure the inter and intra observer error

	Total sample	**Inter-observer repeatability**	**Intra-observer repeatability**
NILMFS	102	20 (19.6%)	20 (19.6%)
XXIUC	-	18	-
UdeA	69	-	16 (20.3%)
Total	171	38 (22.2%)	36 (21.1%)

Wilczak and colleagues (2017) tested the inter-observer repeatability of the Coimbra method five different times. Of those, only the last two tests, "Coimbra A" and "Coimbra B", were recorded using the new Coimbra method, which is the revised version of the original Coimbra method which was used in this study (Henderson et al., 2013; Wilczak et al., 2017). Therefore, the results obtained in both, the CH vs. MA subset and the EB vs. MA subset, were compared only to the values reported in the "Coimbra B" tests (Table 3-3). Wilczak and colleagues calculated the inter-observer repeatability excluding TC and CA features in all measurements, considered missing data as a third scoring category, and only reported the values obtained for the *subscapularis* and the common extensor origin entheses. The same criteria were used to compare the results obtained of Wilczak and colleagues to those reported in this research. Meco (2018) and Salega et al., (2017) reported inter-observer repeatability results by enthesis, and it is unclear if missing data was considered as a third category. The percentage agreement for the *subscapularis* and the common extensor origin from the studies of Meco (2018) and Salega et al., (2017) were also compared to this research.

The Intra-observer repeatability was calculated using both the right and left side of thirty-six individuals. Sixteen of the skeletons belonged to the UdeA skeletal collection and twenty skeletons to the NILMFS collection. The first scoring session was part of the main sampling of the thesis and the second session was done immediately after the main sample was completed. Therefore, the time between the two sessions ranged from 10 to 45 days.

Percentage agreement, Kappa, and Krippendorff's alpha were used to measure repeatability of the new Coimbra method. Krippendorff's alpha was chosen as it calculates disagreements instead of percentage agreement, compares different sample size, and applies to any type of data (Hayes & Krippendorff, 2007). An online calculator was used to calculate both statistics (Freelon, 2010). Krippendorff's minimum threshold value was set at 0.667 following the original author's recommendation (Krippendorff, 2004). Cohen's Kappa was chosen over Krippendorff's alpha to discuss the results, as Kappa is more commonly used in forensic anthropology. Fine porosity, macro-porosity, and cavitation are rare features recorded by the Coimbra method, and the prevalence of the "absent" attribute can reduce the Kappa value. However, no adjustment was made to calculate Kappa because the adjusted result may not reflect the original inter-observer agreement (Sim & Wright, 2005). Instead, the chance of having a prevalence bias was taken into consideration in the discussion.

2.2.6.4.1. Observers

Inter-observer repeatability was calculated based on observations of three different researchers. All had osteology experience, but training and knowledge of the method and of enthesis anatomy were different between the three researchers.

- Charlotte Henderson (CH) is part of the group that developed the new Coimbra method and has worked extensively with entheses. She has published several papers using the method and has trained students and professionals worldwide.

- Edgar Bernal (EB) is an experienced forensic anthropologist that has focused on trauma analysis and identification of skeletonized human remains arriving at the National Institute of Legal Medicine and Forensic Sciences, in Colombia. He had basic osteological understanding of the enthesis and had no knowledge of the Coimbra method prior to this research. He received six-hours of training from Maria Alejandra Acosta (MA) before sampling.

- Maria Alejandra Acosta has worked with entheses during the last five years and has osteological experience. She was trained in the new Coimbra method by CH during several sessions. Discussions about enthesis anatomy and literature review preceded sampling.

3. RESULTS

This chapter presents the results obtained in the statistical analysis and highlights the most relevant outcomes to be considered in the subsequent discussion. The chapter is divided into three major statistical analyses: 1) the repeatability of the methods used in the analysis; 2) the characterization of the EC trends within each of the two skeletal collections; and 3) the effect of traumatic injuries in EC trends of the male Colombian population. The last two analyses include descriptive statistics, and measurements of the relationships and correlations between variables. Age-at-death was controlled for when it was necessary.

Unless, otherwise stated, all the results were reported by skeletal collection, anatomical region, side, bone, and enthesis, in order to allow comparisons to other research. Entheses were grouped into upper limb and lower limb to enable analysis of results from an anatomical perspective. Data were pooled into binary categories e.g., present and absent, according to the hypothesis being tested, or when sample size were not large enough for statistical analysis.

3.1. Repeatability

3.1.1. Inter-observer repeatability

The two statistics used to calculate inter-observer repeatability showed greater agreement between the CH and MA subset than between the EB and MA subset (Table 3-1). The overall percentage agreement between EB and MA was 76%, while the agreement between CH and MA was 83%. However, differences of measurements for Inter-observer repeatability that calculate the agreement observed between the researchers and the agreement expected by chance were major between the two subsets. The Krippendorff's alpha value for overall observations of CH vs. MA reached the lowest suggested acceptable alpha, which is 0.667, while the EB vs. MA subset did not.

Table 3-1. Results of the Inter-observer repeatability statistics by feature.

	CH vs. MA				**EB vs. MA**			
Feature	**% Agree.**	**K. alpha**	**K**	**Interpretation**	**% Agree.**	**K. alpha**	**K**	**Interpretation**
BF Z1	83	**0.734**	0.735	Substantial	69	0.433	0.452	Moderate
ER Z1	91	**0.821**	0.821	Perfect	84	0.519	0.520	Moderate
TC	80	0.643	0.643	Substantial	71	0.399	0.411	Moderate

BF Z2	75	0.624	0.627	Substantial	71	0.314	0.338	Acceptable
ER Z2	78	0.641	0.642	Substantial	73	0.290	0.309	Acceptable
FPO	81	0.656	0.656	Substantial	70	0.316	0.333	Acceptable
MPO	87	**0.748**	0.748	Substantial	81	0.422	0.425	Moderate
CA	91	**0.816**	0.816	Perfect	85	0.494	0.495	Moderate
Overall	83	**0.721**	0.721	Substantial	76	0.405	0.407	Moderate

Krippendorff's alpha values in bold were higher than 0.667. % Agree.= % agreement, K. alpha= Krippendorff's alpha, K= Cohen's Kappa, BF Z1= bone formation zone 1, ER Z1= erosion zone 1, TC= textural change, BF Z2= bone formation zone 2, ER Z2= erosion zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.

The results by feature showed similar trends to the overall results, where the CH vs. MA observations had greater agreement than the EB vs. MA observations. The percentage agreement by feature ranged from 75% (BF Z2) to 91% (CA) in CH vs. MA and from 69% (BF Z1) to 85% (CA) in EB vs. MA. Both subsets evidenced more agreement in the features with less variability i.e., ER (Z1), MPO and CA. Whereas, BF (Z2), ER (Z2), TC and FPO all showed the lowest percentage agreement in both subsets. However, the greatest difference between the two was evidenced in BF (Z1) where CH vs MA showed 83% and EB vs. MA obtained 69%, the lowest percentage agreement of all features.

The Krippendorff's results by feature evidenced the substantial difference between the agreement of two subsets. Four out of the eight features of the CH vs. MA subset reached the acceptable Krippendorff's alpha values i.e., BF (Z1), ER (Z1), MPO and CA, while none of the features of the EB vs. MA subset were at or above the minimum threshold value for acceptance.

The results by enthesis showed that percentage agreement between CH vs. MA observations ranged from 77% (iliopsoas) to 90% (*quadriceps femoris* and *triceps brachii*), while EB vs. MA observations ranged from 67% (patellar ligament) to 80% (Gastrocnemius and *supraspinatus*) (Table 3-2). In general, percentage agreement by enthesis were larger in the CH vs. MA subsets (mean 84%, SD 4.14) than the EB vs. MA subsets (mean 74%, SD 4.38). Except for the patellar ligament, the *quadriceps femoris* and the *triceps brachii*, all entheses showed the same trends in both subsets. In the CH vs. MA subset, the percentage agreement of these entheses were equal to the mean value (patellar ligament 84%) or 2 standard deviations above it (*quadriceps femoris* 90%, *triceps brachii* 90%), whereas in the EB vs. MA subset these entheses were slightly under the mean value (*quadriceps femoris* 73%) or 2 standard deviations under it (patellar ligament 67%, *triceps brachii* 68%).

Table 3-2. Results of the Inter-observer repeatability statistics by enthesis.

	CH vs. MA				**EB vs. MA**			
Enthesis	**% Agree.**	**K**	**Interpretation**	**K. Alpha**	**% Agree.**	**K**	**Interpretation**	**K. Alpha**
Biceps brachii	82	0.696	Substantial	**0.696**	74	0.177	Slight	0.151
CEO	83	0.734	Substantial	**0.733**	78	0.108	Slight	0.083
CFO	78	0.633	Substantial	0.628	71	0.243	Fair	0.241
Gastrocnemius	85	0.699	Substantial	**0.699**	80	-0.043	No agreement	-0.050
Iliopsoas	77	0.605	Moderate	0.604	69	0.249	Fair	0.247
Infraspinatus	81	0.686	Substantial	**0.686**	76	0.252	Fair	0.252
Patella ligament	84	0.611	Substantial	0.610	67	0.191	Slight	0.185
Plantar fascia	89	0.827	Perfect	**0.828**	76	0.313	Fair	0.312
Quadriceps femoris	90	0.839	Perfect	**0.839**	73	0.464	Moderate	0.465
Subscapularis	83	0.727	Substantial	**0.727**	72	0.100	Slight	0.086
Supraspinatus	87	0.767	Substantial	**0.768**	80	0.289	Fair	0.289
Triceps brachii	90	0.803	Substantial	**0.803**	68	0.269	Fair	0.257
Triceps surae	82	0.683	Substantial	**0.683**	74	0.356	Fair	0.356
Vastus Lateralis	88	0.792	Substantial	**0.792**	78	0.553	Moderate	0.552

Krippendorff's alpha values in bold were higher than 0.667. % Agree.= % agreement, K. alpha= Krippendorff's alpha, K= Cohen's Kappa. CEO= Common extensor origin, CFO= common flexor origin.

The results of the Krippendorff's by enthesis confirmed that trends of the two subsets were different. The results showed that eleven out of fourteen (79%) entheses analyzed in the CH vs. MA subset had Krippendorff's values above the lower limit for acceptable conclusions. While none of the entheses recorded by EB and MA reached the lowest threshold for acceptance.

3.1.2. Intra-observer repeatability

The overall agreement of the two statistics were calculated including both the left and the right side in all fourteen entheses studied. The results of the two statistics were higher than all the four inter-observer repeatability tests and the intra-observer test reported by Wilczak et al. (2017), and Meco (2018). The overall percentage agreement reached 86.7% when considering all fourteen entheses (Table 3-3). Percentage agreement by features were similar in all the eight features of the new Coimbra method, ranging between 80% (TC) and 95% (CA), with a mean value of 87% (SD 5.5). Krippendorff's alpha values ranged between 0.664 (BF in zone 2) and 0.868 (CA), with an overall value of 0.738.

Table 3-3. Results of intra-observer repeatability test. Percentage agreement and Krippendorff's alpha by feature.

Feature	% Agreement	K. Alpha	K	Interpretation
BF Z1	84	**0.736**	0.736	Substantial
ER Z1	89	**0.683**	0.683	Substantial
TC	80	**0.667**	0.667	Substantial
BF Z2	81	0.664	0.664	Substantial
ER Z2	84	**0.714**	0.714	Substantial
FPO	88	**0.729**	0.729	Substantial
MPO	93	**0.808**	0.808	Perfect
CA	95	**0.868**	0.868	Perfect
Overall	86.7	**0.738**	0.738	Substantial

Krippendorff's alpha values in bold were higher than 0.667. K. alpha= Krippendorff's alpha, K= Cohen's Kappa. BF Z1= bone formation zone 1, ER Z1= erosion zone 1, TC= textural change, BF Z2= bone formation zone 2, ER Z2= erosion zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.

The percentage agreement by enthesis of the fourteen entheses tested ranged between 79% (*subscapularis* insertion) and 91% (*infraspinatus* insertion), with a mean value of 86% (SD 2.9) (Table 3-4). Krippendorff's alpha values showed the lowest agreement (0.527) in the *subscapularis* insertion, while the *infraspinatus* enthesis obtained the highest intra-observer agreement (0.811). Nine out of fourteen entheses (64%) evidenced Krippendorff's values above the lower suggested limit for acceptance.

The percentage agreement by enthesis reported by Meco ranged from 79% (*biceps brachii*) to 97% (common flexor origin). Except for four entheses, *biceps brachii* (MA 87% vs Meco 79%), *infraspinatus* (MA 91% vs Meco 82%), patellar ligament (MA 87% vs Meco 85%), and *triceps surae* (MA 85% vs Meco 83%), all entheses showed higher percentage agreement in the Meco test than those obtained in this research. Krippendorff's alpha values showed different trends than the percentage agreement of which only two entheses reported by Meco, the common extensor origin (MA 0.784 vs Meco 0.844) and the *subscapularis* (MA 0.527 vs Meco 0.566), obtained higher values than this research. However, the most remarkable difference is in the *infraspinatus* (MA 0.811 vs Meco 0.560) and the patellar ligament (MA 0.730 vs Meco 0.363), where Meco reported two of the lowest Krippendorff's values, and this research obtained values over 0.667. Four out of eleven entheses (36%) reported by Meco showed values above the lower limit for acceptance, the same entheses passed the minimal acceptance threshold in this research, i.e., CEO, CFO, *quadriceps femoris*, and *vastus lateralis*.

Table 3-4. Results of intra-observer repeatability tests by enthesis compared to Meco (2018).

	This research				**Meco (2018)**	
Enthesis	**% Agree.**	**K. Alpha**	**K**	**Interpretation**	**% Agree.**	**K. Alpha**
Biceps brachii	87	**0.722**	0.722	Substantial	79	0.606
CEO	90	**0.784**	0.784	Substantial	94	**0.844**
CFO	85	**0.711**	0.711	Substantial	97	**0.664**
Gastrocnemius	88	0.641	0.642	Substantial		
Iliopsoas	86	**0.685**	0.685	Substantial		
Infraspinatus	91	**0.811**	0.811	Perfect	82	0.56
Patella ligament	87	**0.730**	0.730	Substantial	85	0.363
Plantar fascia	83	0.642	0.641	Substantial		
Quadriceps femoris	85	**0.709**	0.709	Substantial	93	**0.697**
Subscapularis	79	0.527	0.531	Moderate	88	0.566
Supraspinatus	85	0.619	0.619	Substantial	92	0.559
Triceps brachii	83	0.638	0.638	Substantial	88	0.578
Triceps surae	85	**0.691**	0.691	Substantial	83	0.6
Vastus Lateralis	86	**0.745**	0.745	Substantial	89	**0.718**

Krippendorff's alpha values in bold were higher than 0.667. % Agree.= % agreement, K. alpha= Krippendorff's alpha, K= Cohen's Kappa. CEO= common extensor origin, CFO= common flexor origin.

3.2. Objective 1. Population variability

3.2.1. Upper limbs

3.2.1.1. *Descriptive and inferential statistics*

3.2.1.1.1. Skeletal Collection of the University of Antioquia - UdeA.

The sample from the UdeA skeletal collection was composed of 69 male individuals, most of which had an age-at-death ranging from 20 to 35 years (50.7%). Surface preservation of bone and completeness of skeleton allowed to record 84.4% of entheses to be recorded.

The frequencies of the eight features recorded by the Coimbra method, in seven entheses of the upper limbs are presented below (Appendix 2). The entheses of the upper extremities could be recorded in 72% to 97% of the individuals depending on the enthesis. The zone 1 was recordable on average in 82% of individuals analyzed, SD 7%; while zone 2 was better preserved being recordable on average in 87% of individuals, and SD 8%. The *subscapularis* and *biceps brachii*, of both the right and the left sides were the most observable entheses of all, ranging from 88% to 94% (respectively) in zone 1, and 96% to 97% in zone 2. While *infraspinatus*, common extensor and common flexor on the left side were the entheses with the greatest missing values, ranging from 23% to 27% of unobservable cases. Non-observable features of the right *infraspinatus* ranged from 19% to 22%, common flexor 17%, and common extensor 9% to 16%. Except for the left common flexor, the zone 2 of all entheses was observed more frequently than zone 1.

General trends of score “1” in entheses located in the upper limbs of male individuals from the UdeA skeletal collection showed that bone formation in zone 1 is the most common feature of all (mean 20.3%, SD 17.4%, median 17.4%); followed by bone formation zone 2 (mean 15.8%, SD 9.3%, median 14.5%), and erosion in zone 2 (mean 14.8%, SD 7.8%, median 10.9%). Textural change was more varied than the other features (mean 14%, SD 16.9%, median 9.4%). Erosion in zone 1 (mean 3.5%, SD 5%, median 1.4%), fine porosity and macro-porosity (mean 3%, SD 2%, median 3%) showed similar distribution between each other. Cavitation was the least common feature of all (mean 0.4 SD 0.9, median 0%).

Except for fine porosity, macro-porosity, and cavitation, all the features had the highest scores in the *biceps brachii* enthesis. Fine porosity and macro-porosity have low frequencies overall, with most of the cases recorded in the three entheses forming the rotator cuff i.e., *subscapularis*, *supraspinatus*, and *infraspinatus*, none of which were scored as “2”. The right *subscapularis* (7,2%) and the left *triceps brachii* (7,2%) showed the most cases of macro-porosity. Cavitation was the least common feature of all (0,8%). It is remarkable that 4 of 6 cavitations recorded in the UdeA collection were found in the *subscapularis* enthesis.

Score “2” was rarely recorded in any of the entheses. When recorded, it was mainly in bone formation in zone 1 (mean 3.0%, SD 4.5%, median 0.7%) and erosion in zone 2 (mean 1.64%, SD 2.4%, median 0.7%). The *biceps brachii* insertion showed the greatest frequency of score 2 for all upper limb entheses, in which 10% to 15% of bone formation (Z1) met the criteria for score 2. The *triceps brachii* on both sides, and the right common extensor origin reported more than one case of bone formation (Z2) scored as 2. The same was true for the erosion (Z2) on the *biceps brachii* of both upper limbs (ranging from 4.3% and 7.2%), and the right *subscapularis* (5.3%). Erosion (Z1) and cavitation evidenced one or two individuals meeting the criteria for score 2 in some of the rotator cuff entheses. Fine porosity and macro-porosity showed no cases of score 2. Note that textural change can only score 0 or 1.

Frequencies of score 1 and score 2 were pooled into presence. Frequencies of presence demonstrate that the *biceps brachii* insertion showed the most variability for EC features within the entheses of the upper limbs of both the right (26%) and the left side (27%). The *triceps brachii* of both sides, and the *subscapularis* in the right and the left side also showed high frequency of ECs (Table 3-5). The *biceps brachii* insertion and the *triceps brachii* insertion were the entheses with the highest presence of bone formation (Z1), textural change and erosion (Z2), in both the left and the right upper limbs. The same two entheses evidenced greater frequencies of bone formation (Z2) in the left upper limb only. Trends of both upper limbs showed that the presence of erosion (Z1) was higher in the *biceps brachii* (left 13%, right 16%) and the *subscapularis* insertion (left 8%, right 8%) than any other enthesis. The same was true for bone formation (Z2) on the *biceps brachii* (36%) and the *subscapularis* (30%) of the right limb.

The presence of EC within the three age groups evidenced different trends in each feature, each enthesis, and each side (Appendix 3). In general, bone formation and macro-porosity are more common in older individuals, while textural change and fine porosity tends to be more frequent within young and middle adults. Moreover, the differences of ECs between the age ranges were more evident in the right side compared to the left side, where young and middle adults had more ECs in the right side and older individuals in the left side.

The results of the Likelihood-Ratio test showed that proportions of five out of the eight features recorded by the Coimbra method were different between the three age groups in at least two entheses (Table 3-6). Most of the entheses (71%) showed differences in the presence of bone formation in zone 1 and erosion in zone 2 between the three age groups, Cramer's V values ≥0.3. Bone formation in zone 2 (36%), followed the same trend in fewer entheses, but the Cramer's V values were slightly higher than bone formation (Z1) and erosion (Z2) (≥ 0.4). Macro-porosity showed a statistically significant difference in three out of the fourteen entheses analyzed in the upper limbs (21%), all of which had Cramer's V values ≥0.3. While erosion in zone 1 had significant differences between the age ranges in two entheses (14%) with a Cramer's V value ≥0.5 on the left side and a Cramer's V value ≤0.3 on the right side. Opposite trends were observed in textural change, fine porosity, and cavitation features, in which none of the entheses recorded showed a significant difference in EC presence within the age groups.

The results of the Likelihood-Ratio test showed that the common extensor origin was the only enthesis with both strong and bilateral significant difference within the age groups in three out of the eight features recorded, i.e., bone formation (Z1) and (Z2), and erosion (Z2), with Cramer's V values ≥0.3. All the other entheses in the upper limbs had bilateral differences in one feature and asymmetrical differences in others, with Cramer's V values ≥0.3. The *biceps brachii* insertion showed differences in the presence of bone formation (Z1) and erosion (Z2) between the age ranges in both the left and the right sides, but proportions of macro-porosity presence in the *biceps brachii* insertion were different only in the left side. The common flexor origin and the *supraspinatus* insertion had different proportions in the presence of erosion (Z2) in both the left and the right side. The presence of bone formation in both zone 1 and zone 2 were significantly different in the left side of the common flexor origin. The presence of bone formation (Z1) and erosion (Z1) in the left limb and macro-porosity in the right *supraspinatus* insertion were also different between the three age ranges. The *triceps brachii* insertion evidenced that the presence of bone formation (Z1) was different in both the left and the right side, the presence of bone formation (Z2) was different in the left side, while the presence of erosion (Z2) was different in the right side. The left and the right *subscapularis* entheses evidenced that the presence of bone formation in both zone 1 and zone 2 showed significant differences between the three age ranges. The Likelihood-Ratio test also showed that the presence of erosion in (Z1) and (Z2), and macro-porosity was significantly different in the right *subscapularis*. The insertion of the *infraspinatus* in both the right and the left side was the only enthesis showing that the effect of age was not significant for any of the eight features recorded.

Table 3-5. Frequencies of pooled score 1 and 2 by enthesis and side. Upper limbs UdeA

		BF (Z1)			ER (Z1)			TC			BF (Z2)			ER (Z2)			FPO			MPO			CA			Variability		
Side	**Enthesis**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**
Left	Biceps brachii	63	48	76%	63	8	13%	66	41	62%	66	19	29%	66	21	32%	66	2	3%	66	2	3%	66	1	2%	522	142	27%
	Common extensor	50	13	26%	50	0	0%	53	2	4%	53	8	15%	53	6	11%	53	1	2%	53	1	2%	53	0	0%	418	31	7%
	Common flexor	53	7	13%	53	1	2%	52	2	4%	52	4	8%	52	8	15%	52	0	0%	52	0	0%	52	0	0%	418	22	5%
	Infraspinatus	51	0	0%	51	0	0%	52	4	8%	52	5	10%	52	6	12%	52	3	6%	52	1	2%	52	0	0%	414	19	5%
	Subscapularis	61	12	20%	61	5	8%	66	7	11%	66	15	23%	67	12	18%	67	3	4%	67	2	3%	67	2	3%	522	58	11%
	Supraspinatus	55	3	5%	55	4	7%	61	7	11%	61	1	2%	61	6	10%	61	4	7%	61	1	2%	61	0	0%	476	26	5%
	Triceps brachii	56	21	38%	56	0	0%	58	11	19%	58	15	26%	58	14	24%	58	2	3%	58	5	9%	58	0	0%	460	68	15%
	Total	389	104	27%	389	18	5%	408	74	18%	408	67	16%	409	73	18%	409	15	4%	409	12	3%	409	3	1%	3230	366	11%
Right	Biceps brachii	64	44	69%	64	10	16%	67	31	46%	67	24	36%	67	24	36%	67	1	1%	67	2	3%	67	0	0%	530	136	26%
	Common extensor	56	20	36%	56	0	0%	62	2	3%	62	13	21%	62	8	13%	62	0	0%	62	1	2%	62	0	0%	484	44	9%
	Common flexor	55	9	16%	55	0	0%	55	1	2%	55	12	22%	55	5	9%	55	3	5%	55	1	2%	55	0	0%	440	31	7%
	Infraspinatus	52	1	2%	52	1	2%	54	7	13%	54	7	13%	54	6	11%	54	5	9%	54	3	6%	54	0	0%	428	30	7%
	Subscapularis	65	22	34%	65	5	8%	67	6	9%	67	20	30%	67	19	28%	67	4	6%	67	5	7%	67	2	3%	532	83	16%
	Supraspinatus	52	2	4%	52	1	2%	62	6	10%	62	6	10%	62	7	11%	62	2	3%	62	3	5%	62	1	2%	476	28	6%
	Triceps brachii	52	25	48%	52	1	2%	55	8	15%	55	9	16%	55	18	33%	55	2	4%	55	2	4%	55	0	0%	434	65	15%
	Total	396	123	31%	396	18	5%	422	61	14%	422	91	22%	422	87	21%	422	17	4%	422	17	4%	422	3	1%	3324	417	13%

BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.

Table 3-6. Results of Likelihood-Ratio test by enthesis and side, showing differences between the three age groups.

	Left								Right							
Enthesis	**BF (Z1)**	**ER(Z1)**	**TC**	**BF(Z2)**	**ER(Z2)**	**FPO**	**MPO**	**CA**	**BF (Z1)**	**ER(Z1)**	**TC**	**BF(Z2)**	**ER(Z2)**	**FPO**	**MPO**	**CA**
Biceps brachii																
N	63	63	66	66	66	66	66	66	64	64	67	67	67	67	67	67
LR	9.59	1.12	3.98	0.54	7.60	1.12	6.76	3.31	10.49	1.28	3.11	0.05	7.75	2.56	1.68	NaN
df	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
p-value	**0.008**	0.572	0.137	0.763	**0.022**	0.572	**0.034**	0.191	**0.005**	0.528	0.212	0.974	**0.021**	0.278	0.433	
Cramer's V	**0.32**	0.12	0.25	0.09	**0.34**	0.11	**0.36**	0.25	**0.39**	0.14	0.21	0.03	**0.35**	0.20	0.14	NaN
Common extensor origin																
N	50	50	53	53	53	53	53	53	56	56	62	62	62	62	62	62
LR	13.35	NaN	1.35	12.67	6.48	1.29	1.29	NaN	18.45	NaN	2.92	14.05	13.86	NaN	2.66	NaN
df	2		2	2	2	2	2		2		2	2	2		2	
p-value	**0.001**		0.508	**0.002**	**0.039**	0.524	0.524		**< .001**		0.232	**0.001**	**0.001**		0.264	
Cramer's V	**0.52**	NaN	0.14	**0.53**	**0.38**	0.13	0.13	NaN	**0.55**	NaN	0.19	**0.44**	**0.43**	NaN	0.21	NaN
Common flexor origin																
N	53	53	52	52	52	52	52	52	57	57	57	57	57	57	57	57
LR	9.49	1.22	3.19	7.82	7.25	NaN	NaN	NaN	1.97	NaN	3.02	2.31	10.63	1.76	1.30	NaN
df	2	2	2	2	2				2		2	2	2	2	2	
p-value	**0.009**	0.543	0.203	**0.02**	**0.027**				0.374		0.221	0.315	**0.005**	0.415	0.522	
Cramer's V	**0.46**	0.13	0.22	**0.38**	**0.36**	NaN	NaN	NaN	0.19	NaN	0.25	0.20	**0.44**	0.14	0.13	NaN
Infraspinatus																
N	51	51	52	52	52	52	52	52	54	54	56	56	56	56	56	54
LR	NaN	NaN	0.01	3.74	3.35	1.63	3.00	NaN	2.75	NaN	0.10	1.61	0.61	0.61	3.36	NaN
df			2	2	2	2	2		2		2	2	2	2	2	
p-value			0.994	0.154	0.187	0.442	0.223		0.252		0.952	0.447	0.736	0.738	0.186	
Cramer's V	NaN	NaN	0.02	0.29	0.25	0.14	0.26	NaN	0.23	NaN	0.04	0.17	0.10	0.11	0.24	NaN
Subscapularis																
N	61	61	66	66	67	67	67	67	65	65	67	67	67	67	67	67
LR	8.12	3.67	0.76	20.32	3.04	1.56	2.91	2.91	25.89	7.69	0.20	15.71	6.73	2.53	8.00	2.91
df	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
p-value	**0.017**	0.16	0.683	**< .001**	0.219	0.458	0.233	0.233	**< .001**	**0.021**	0.904	**< .001**	**0.035**	0.282	**0.018**	0.233
Cramer's V	**0.37**	0.27	0.10	**0.54**	0.22	0.12	0.18	0.18	**0.60**	**0.31**	0.06	**0.47**	**0.31**	0.16	**0.31**	0.18
Supraspinatus																
N	55	55	61	61	61	61	61	61	56	56	62	62	62	62	62	62
LR	9.24	12.62	0.53	3.00	13.62	0.01	3.00	NaN	5.77	2.83	4.21	3.60	6.01	1.57	9.48	3.03
df	2	2	2	2	2	2	2		2	2	2	2	2	2	2	2

p-value	**0.01**	**0.002**	0.768	0.223	**0.001**	0.994	0.223		0.056	0.243	0.122	0.165	**0.05**	0.457	**0.009**	0.219
Cramer's V	**0.43**	**0.50**	0.09	0.24	**0.48**	0.02	0.24	NaN	0.33	0.23	0.22	0.24	**0.32**	0.14	**0.42**	0.24
Triceps brachii																
N	56	56	58	58	58	58	58	58	53	53	56	56	56	56	56	56
LR	14.246	NaN	4.729	4.643	1.981	2.704	3.928	NaN	25.672	2.717	2.466	0.583	8.69	1.28	1.577	NaN
df	2		2	2	2	2	2		2	2	2	2	2	2	2	
p-value	**0.001**		0.094	0.098	0.371	0.259	0.14		**< .001**	0.257	0.291	0.747	**0.013**	0.527	0.454	
Cramer's V	**0.50**	NaN	0.30	0.29	0.18	0.18	0.24	NaN	**0.67**	0.23	0.21	0.11	**0.39**	0.13	0.15	NaN

Bold numbers indicate significance at 0.05 level. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.

3.2.1.1.2. National Institute of Legal Medicine and Forensic Sciences Skeletal collection- NILMFS

The sample from the NILMFS skeletal collection comprised 102 male individuals, who were almost equally distributed among the three age ranges (31.4% to 35.3%). Most individuals evidenced skeletal completeness and excellent surface preservation of bones, allowing the recording of 90.8% of their entheses. Some individuals evidenced remains of adipocere near to the joint surfaces, which limited the observation of such entheses and joints.

Despite the presence of soft tissue remnants, more entheses in the upper limbs were recorded in this collection than UdeA, varying from 77.5% to 98%. Zone 1 was recordable on average 90%, SD 6% of the individuals; and zone 2 was recordable on average 91%, SD 5% of the sampled individuals (Appendix 4). Similar to the UdeA skeletal collection, the most observable entheses were the *subscapularis* of both the left and the right side, and the right *biceps brachii*. The percentage of observable enthesis of those three entheses ranged from 96% to 98% in zone 1, and 96% to 97% in zone 2. The common flexor origin was the enthesis with the greatest non-recordable values in both the left and the right side, where percentage of observable enthesis were as low as 77% in zone 1 and 79% in zone 2. All the other entheses showed higher sample size in zone 2 than in zone 1, except for the left *subscapularis*, the left common extensor, and both sides of the *biceps brachii*.

General trends of EC in the upper limbs of the NILMFS collection showed that frequencies of the eight features were highly divergent between entheses. As seen in the UdeA skeletal collection, frequencies of the score “1” evidenced that bone formation in zone 1 is the most common feature of all (mean 25.4%, SD 17.21; median 23.1%), followed by bone formation in zone 2 (mean 21.6%, SD 8.42; median 19.6%). Textural change (mean 16.7%, SD 20.22; median 9.8%) and erosion in zone 2 (mean 16.5%, SD 5.68; median 16.7%) shared the same arithmetic mean. However, the standard deviation of both features evidenced that the mean of the textural change is increased exclusively by the high frequencies of the *biceps brachii*, while the mean of the erosion (Z2) is more equally distributed within all entheses. Fine porosity (mean 9.7%, SD 3.55; median 9.3%) is present in all entheses, but mainly found in the right *supraspinatus* (14.7%) and the right common extensor entheses (14.7%). Erosion in zone 1 (mean 5.1%, SD 4.19; median 3.9%), macro-porosity (media 4.1%, SD 2.9; median 3.58%), and cavitation (mean 2.3%, SD 2.85; median 1.5%) were the least common features.

The right and the left *biceps brachii* insertion had the highest frequencies for bone formation in zone 1 (right 60%, left 55%), and textural change (right 66%, left 61%). While *subscapularis* in both the right and the left side showed the highest frequencies of erosion in zone 2 (right 29.4%, left 20.6%), macro-porosity (right 12.7%, left 9.8%), and cavitation (right 7.8%, left 8.8%). Erosion in zone 1 indicates that *subscapularis* in the left (14.7%), but not the right side (7.8%), is the enthesis with highest frequencies. Except for fine porosity, the *supraspinatus* (right 14.7%, left 12.7%) and the *infraspinatus* insertions (right 6.9%, left 13.7%), in both the right and the left side, were the entheses showing the least amount of change overall. However, the same two entheses evidenced the opposite trend in the fine porosity feature compared with the other seven features in which the frequencies of both sides were the highest within all entheses.

General trends of EC frequencies of score “2” showed a low variability for all features in all entheses. As seen in the UdeA skeletal collection, the most variable features were bone formation in zone 1 and erosion in zone 2. Bone formation in zone 1 of both sides of the *biceps brachii* insertion showed (10.8%) the highest frequencies of all entheses in the upper limbs. Whereas erosion in zone 2 of the *supraspinatus* insertion, in both the right (score “1”= 6.9%, score “2”= 7.8%) and the left side (score “1”= 6.9%, score “2”= 6.9%), “score 2” showed either equal to, or higher frequencies than “score 1”.

Pooled frequencies of EC presence in the entheses of the upper limbs were summarized by side and feature (Table 3-7). Bone formation (Z1) showed high frequencies in all entheses but the left *supraspinatus* and the *infraspinatus* insertion of both, the left and the right side. Of those, the *biceps brachii* insertion had the highest frequencies of bone formation (Z1) and textural change of all entheses in both the left and the right upper limbs. However, textual change evidenced the opposite general trend in which low frequencies were seen in all entheses except for the *biceps brachii* insertion. The same was true for erosion (Z1) in which all entheses had low frequencies. Of these, both the left and the right *subscapularis* and the *biceps brachii* insertion had the highest presence of erosion (Z1) of all. Bone formation (Z2) and erosion (Z2) showed the lowest frequencies of all in the *supraspinatus* insertion (≥ 12%) of both upper limbs and the highest values in the *subscapularis* insertion of both the left and the right side (ranged from 25.3% and 41.4%). Fine porosity evidenced different trends on each upper limb, while in the left side the three entheses forming the rotator cuff counted for 60% of the total changes reported, with the *supraspinatus* being the enthesis with the most presence of fine porosity. In the right side, the same trio of entheses counted for 46.5% of the total changes reported, of which the *supraspinatus* evidenced most of the fine porosity. The left common extensor origin showed the same frequencies as the *supraspinatus*. Macro-porosity and cavitation features showed the highest frequencies in the *subscapularis* enthesis in both the left and the right side. Frequencies of the three entheses of the rotator cuff i.e., *subscapularis, supraspinatus,* and *infraspinatus*, accounted for 87.5% in the left side and 83.3% in the right side of all cavitations reported in the upper limbs of the NILMFS skeletal collection.

Table 3-7. Frequencies of EC presence by side and enthesis in the upper limbs of NILMFS skeletal collection.

		BF (Z1)			ER (Z1)			TC			BF (Z2)			ER (Z2)			FPO			MPO			CA			Variability		
Side	**Enthesis**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**
Left	Subscapularis	100	34	34.0	100	18	18.0	99	10	10.1	99	37	37.4	99	25	25.3	99	13	13.1	99	12	12.1	99	9	9.1	794	158	20%
	Supraspinatus	94	6	6.4	94	8	8.5	96	9	9.4	96	12	12.5	96	14	14.6	96	15	15.6	96	4	4.2	96	1	1.0	764	69	9%
	Infraspinatus	93	5	5.4	93	1	1.1	94	8	8.5	94	22	23.4	94	16	17.0	94	14	14.9	94	2	2.1	94	4	4.3	750	72	10%
	Common extensor	94	30	31.9	94	3	3.2	93	11	11.8	93	30	32.3	93	15	16.1	93	7	7.5	93	3	3.2	93	0	0.0	746	99	13%
	Common flexor	83	19	22.9	83	3	3.6	88	1	1.1	88	22	25.0	88	18	20.5	88	5	5.7	88	2	2.3	88	0	0.0	694	70	10%
	Biceps brachii	97	67	69.1	97	10	10.3	95	62	65.3	95	22	23.2	95	16	16.8	95	5	5.3	95	5	5.3	95	2	2.1	764	189	25%
	Triceps brachii	84	35	41.7	84	5	6.0	88	17	19.3	88	17	19.3	88	17	19.3	88	11	12.5	88	2	2.3	88	0	0.0	696	104	15%
Right	Subscapularis	98	36	36.7	98	11	11.2	99	5	5.1	99	41	41.4	99	38	38.4	99	11	11.1	99	14	14.1	99	8	8.1	790	164	21%
	Supraspinatus	94	15	16.0	94	3	3.2	95	10	10.5	95	13	13.7	95	15	15.8	95	15	15.8	95	6	6.3	95	3	3.2	758	80	11%
	Infraspinatus	94	7	7.4	94	1	1.1	96	7	7.3	96	17	17.7	96	20	20.8	96	7	7.3	96	4	4.2	96	4	4.2	764	67	9%
	Common extensor	89	30	33.7	89	4	4.5	90	12	13.3	90	26	28.9	90	19	21.1	90	15	16.7	90	8	8.9	90	1	1.1	718	115	16%
	Common flexor	79	18	22.8	79	1	1.3	81	3	3.7	81	19	23.5	81	21	25.9	81	9	11.1	81	0	0.0	81	0	0.0	644	71	11%
	Biceps brachii	99	72	72.7	99	10	10.1	98	67	68.4	98	18	18.4	98	16	16.3	98	7	7.1	98	3	3.1	98	2	2.0	786	195	25%
	Triceps brachii	86	48	55.8	86	6	7.0	91	16	17.6	91	18	19.8	91	21	23.1	91	7	7.7	91	1	1.1	91	0	0.0	718	117	16%

BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.

Like the UdeA skeletal collection, the frequencies of the EC by age groups evidenced that most of the features of all entheses had the highest presence in the oldest individuals. Except for textural change and fine porosity that showed the opposite trend in which younger individuals evidenced higher presence of EC than the oldest ones (Appendix 5). The results of the Chi squared test showed that the presence of EC was different between the three age groups in most of the entheses (Table 3-8). Cramer's V values ranged from 0.20 to 0.62. The strongest difference was observed in bone formation in both zone 1 and 2, and erosion (Z2) features, followed by erosion (Z1) and textural change features. The differences of fine porosity, macro-porosity, and cavitation between the three age ranges had the smallest Cramer's V values of all <0.3.

The entheses of both sides of the common extensor, the common flexor, the *biceps brachii* and the *triceps brachii* evidenced that the presence of bone formation (Z1) was different between the age ranges. The same was true in the *subscapularis* and the *infraspinatus* on the left, but not the right limb. The effect size values calculated for the bone formation (Z1) features were the highest within all features. The presence of bone formation (Z2) was different in the *subscapularis* and the common extensor of both sides, the right *infraspinatus*, and the left common flexor. All the entheses on the right side, except for the biceps and *triceps brachii*, evidenced that the presence of erosion (Z2) was significantly different between the age ranges. The same was true in the common flexor on the left side. The presence of erosion (Z1) was different between the age ranges in the *subscapularis* insertion of both the left and the right side. As stated above, in general, the presence of textural change was higher in the youngest individuals, however the left *triceps brachii* evidenced the opposite trend and was the only enthesis evidencing significant differences between the age groups.

Table 3-8. Pearson Chi squared test, Likelihood-Ratio test, and Cramer's V by enthesis and age groups. Upper limbs of the NILMFS skeletal collection.

	Left								**Right**							
Enthesis	**BF (Z1)**	**ER(Z1)**	**TC**	**BF(Z2)**	**ER(Z2)**	**FPO**	**MPO**	**CA**	**BF (Z1)**	**ER(Z1)**	**TC**	**BF(Z2)**	**ER(Z2)**	**FPO**	**MPO**	**CA**
Biceps brachii																
N	97	97	95	95	95	95	95	95	99	99	98	98	98	98	98	98
X^2	26.52	2.84*	0.07	5.21	6.98	1.41*	6.95*	4.85*	15.97	1.26*	2.83	6.46	3.39	2.28*	3.05*	1.80*
df	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
p-value	**< .001**	0.242	0.967	0.074	**0.031**	0.495	**0.031**	0.089	**< .001**	0.534	0.243	**0.039**	0.184	0.32	0.218	0.408
Cramer's V	**0.52**	0.16	0.03	0.23	**0.27**	0.13	**0.26**	0.22	**0.40**	0.11	0.17	**0.26**	0.19	0.15	0.16	0.11
Common extensor origin																
N	94	94	93	93	93	93	93	93	89	89	90	90	90	90	90	90
X^2	20.26	3.05*	1.87*	14.70	4.21	0.46*	3.05*	NaN	29.93	3.68*	0.77*	16.31	11.69	5.36	2.62*	NaN
df	2	2	2	2	2	2	2		2	2	2	2	2	2	2	
p-value	**< .001**	0.217	0.393	**< .001**	0.122	0.796	0.218		**< .001**	0.159	0.681	**< .001**	**0.003**	0.069	0.27	
Cramer's V	**0.46**	0.16	0.14	**0.40**	0.21	0.07	0.16	NaN	**0.58**	0.16	0.09	**0.43**	**0.36**	0.24	0.16	NaN
Common flexor origin																
N	83	83	88	88	88	88	88	88	79	79	81	81	81	81	81	81
X^2	28.52	2.42*	2.18*	19.75	20.79	6.35*	1.85*	NaN	19.35	2.17*	3.34*	4.37	13.04	6.49*	NaN	NaN
df	2	2	2	2	2	2	2		2	2	2	2	2	2		
p-value	**< .001**	0.298	0.337	**< .001**	**< .001**	**0.042**	0.398		**< .001**	0.338	0.188	0.112	**0.001**	**0.039**		
Cramer's V	**0.59**	0.15	0.15	**0.47**	**0.49**	**0.25**	0.12	NaN	**0.50**	0.16	0.18	0.23	**0.40**	**0.29**	NaN	NaN
Infraspinatus																
N	93	93	94	94	94	94	94	94	94	94	96	96	96	96	96	96
X^2	12.68*	NaN	2.57*	6.57	7.74	5.93*	4.80*	3.70*	8.34*	NaN	0.38*	13.92	12.66	6.00*	4.71*	3.59*
df	2		2	2	2	2	2	2	2		2	2	2	2	2	2
p-value	**0.002**		0.277	**0.038**	**0.021**	0.052	0.091	0.158	**0.015**		0.828	**< .001**	**0.002**	**0.05**	0.095	0.166
Cramer's V	**0.36**	NaN	0.16	**0.26**	**0.29**	0.23	0.22	0.16	**0.27**	NaN	0.06	**0.38**	**0.36**	**0.20**	0.20	0.15
Subscapularis																
N	100	100	99	99	99	99	99	99	98	98	99	99	99	99	99	99
X^2	20.40	18.37	1.29*	20.05	11.43	0.35	11.62*	8.30*	5.86	16.52*	1.33*	16.96	10.09	1.10	3.60*	3.90*
df	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

p-value	**< .001**	**< .001**	0.526	**< .001**	0.003	0.842	**0.003**	**0.016**	0.053	**< .001**	0.515	**< .001**	**0.006**	0.578	0.165	0.142
Cramer's V	**0.45**	**0.43**	0.12	**0.45**	0.34	0.06	**0.29**	**0.24**	0.25	**0.39**	0.12	**0.41**	**0.32**	0.11	0.18	0.20
Supraspinatus																
N	94	94	96	96	96	96	96	96	94	94	95	95	95	95	95	95
X^2	3.50*	8.15*	0.98*	11.02*	3.53*	2.43	0.64*	2.35*	7.61	2.91*	1.29*	8.55*	11.66	2.20	6.53*	7.35*
df	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
p-value	0.174	**0.017**	0.612	**0.004**	0.171	0.197	0.728	0.309	**0.022**	0.234	0.526	**0.014**	**0.003**	0.334	**0.038**	**0.025**
Cramer's V	**0.20**	**0.25**	0.10	**0.27**	0.18	0.16	0.08	0.15	**0.29**	0.15	0.12	**0.29**	**0.35**	0.15	**0.23**	**0.27**
Triceps brachii																
N	84	84	88	88	88	88	88	88	86	86	91	91	91	91	91	91
X^2	18.93	1.44*	10.52	1.61	2.27	1.95*	1.56*	NaN	33.42	6.46*	3.87	6.54	3.57	0.20*	2.18*	NaN
df	2	2	2	2	2	2	2		2	2	2	2	2	2	2	
p-value	**< .001**	0.486	**0.005**	0.446	0.321	0.377	0.458		**< .001**	**0.04**	0.145	**0.038**	0.167	0.904	0.337	
Cramer's V	**0.48**	0.14	**0.35**	0.14	0.16	0.15	0.11	NaN	**0.62**	**0.24**	0.21	**0.27**	0.20	0.05	0.15	NaN

*Bold indicate significance at 0.05 level. * Indicates that Likelihood-Ratio test was used instead of the Pearson Chi squared test. Likelihood-Ratio test was used when Pearson's assumptions were violated. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.*

3.2.1.2. *Comparison between both skeletal collections*

3.2.1.2.1. General trends of entheseal changes

Generalized linear models (GLM) were performed for each side of each enthesis to test whether the "age range" or the "collection" affect the presence of EC in the male Colombian individuals (Table 3-9). The GLM test included both the model with interactions and without interactions between variables. The GLM results indicated that all entheses on the left side were impacted by age category, except for the entheses of the biceps and *triceps brachii* muscles. The GLM model with interactions of the entheses of the left side evidenced that age was not a relevant factor in the EC presence of the *infraspinatus* enthesis. The entheses of *infraspinatus* and the common flexor origin on the left side were affected by the collection, but only in the model without interactions. However, the collection no longer affected the enthesis of the common flexor origin after the Bonferroni correction.

Table 3-9. Results of the GLM for each enthesis in the upper limbs using age range and collection as predictors.

	Side	Parameter	Subscapularis	Supraspinatus	Infraspinatus	Common extensor o.	Common flexor o.	Biceps brachii	Triceps brachii
NILMFS	Left	EC presence	68	41	47	56	40	91	66
		N	102	102	102	102	102	102	102
UdeA		EC presence	35	18	17	25	14	64	41
		N	69	69	69	69	69	69	69
GLM model with interactions		AICC	30.970	31.846	29.636	31.082	29.954	26.223	34.944
		(Intercept)	0.000	0.001	0.002	0.000	0.000	0.007	0.501
		Collection	0.249	0.538	0.288	0.115	0.428	0.055	0.153
		Age	**<0.001***	**0.011***	0.092	**<0.001***	**<0.001***	0.435	0.973
		Collection*Age	0.497	0.875	0.913	0.307	0.895	0.077	0.083
GLM model without interactions		AICC	29.310	29.775	27.647	30.038	28.114	28.040	36.025
		(Intercept)	0.000	0.000	0.000	0.000	0.000	0.005	0.454
		Collection	0.170	0.240	**0.014***	0.070	**0.050**	0.369	0.705
		Age	**<0.001***	**<0.001***	**0.007***	**<0.001***	**<0.001***	0.267	0.052
	Right	EC presence	73	44	43	53	41	95	72
		N	102	102	102	102	102	102	102
		EC presence	41	21	19	27	21	60	41
		N	69	69	69	69	69	69	69
GLM model with interactions		AICC	31.609	33.270	33.982	28.728	29.939	22.992	34.144
		(Intercept)	0.011	0.002	0.000	0.000	0.002	0.506	0.078
		Collection	0.065	0.637	0.932	**0.049**	0.875	0.089	0.690
		Age	**<0.001***	**0.028**	**0.004***	**<0.001***	**0.025**	**0.030**	**0.020**
		Collection*Age	0.134	0.970	0.578	0.074	0.885	0.152	0.964
GLM model without interactions		AICC	32.596	31.174	32.218	30.464	27.863	23.310	32.050
		(Intercept)	0.008	0.000	0.000	0.000	0.000	0.510	0.012
		Collection	0.298	0.240	0.219	0.412	0.450	0.310	0.368
		Age	**<0.001***	**<0.001***	**<0.001***	**<0.001***	**<0.001***	**0.042**	**<0.001***

*Bold indicates significance at 0.05 level. * Indicates significance at 0.05 level after the Bonferroni correction.*

On the right side, both models showed that the presence of EC was affected by age in all entheses. For the GLM with no interactions, age remained statistically significant after the

Bonferroni correction for the entheses of the *subscapularis*, the *infraspinatus*, and the common extensor origin muscles. In the model with interactions, age continued to affect all the entheses despite the Bonferroni correction, apart from the *biceps brachii* insertion. The GLM model with interactions also showed that the collection affected the common extensor origin, but this trend was no longer significant after application of the Bonferroni correction.

The pooled proportions of both skeletal collections were presented by side and enthesis (Table 3-10). The general trend showed that the proportions of EC present in the entheses of the upper limbs of the male individuals from the NILMFS skeletal collection were higher than the proportions of EC present in the upper limbs of the male individuals from the UdeA skeletal collection, except for the left *biceps brachii* that showed the opposite trend. Like the results of GLM models, the Pearson Chi squared test evidenced that the differences between the two skeletal collections are mainly in the entheses of the left side (57.1%). However, all the Cramer's V values were ≤0.22.

Table 3-10. Pooled frequencies of EC presence, Chi squared test of the entheses in the upper limbs.

		NILMFS			**UdeA**			**Pearson Chi-square**			
Enthesis	**Side**	**n**	**f**	**%**	**n**	**f**	**%**	**Value**	**df**	***p*-value**	**V**
Subscapularis	Left	102	68	66.7	69	35	50.7	4.37	1	**0.037**	0.16
	Right	102	73	71.6	69	41	59.4	2.73	1	0.098	0.13
Supraspinatus	Left	102	41	40.2	69	18	26.1	3.63	1	0.057	0.15
	Right	102	44	43.1	69	21	30.4	2.82	1	0.093	0.13
Infraspinatus	Left	102	47	46.1	69	17	24.6	8.08	1	**0.004**	0.22
	Right	102	43	42.2	69	19	27.5	3.81	1	0.051	0.15
Common extensor origin	Left	102	56	54.9	69	25	36.2	5.76	1	**0.016**	0.18
	Right	102	53	52.0	69	27	39.1	2.72	1	0.099	0.13
Common flexor origin	Left	102	40	39.2	69	14	20.3	6.82	1	**0.009**	0.2
	Right	102	41	40.2	69	21	30.4	1.7	1	0.193	0.1
Biceps brachii	Left	102	91	89.2	69	64	92.8	0.61	1	0.436	0.06
	Right	102	95	93.1	69	60	87.0	1.85	1	0.173	0.1
Triceps brachii	Left	102	66	64.7	69	41	59.4	0.49	1	0.483	0.05
	Right	102	72	70.6	69	41	59.4	2.29	1	0.13	0.12

Bold numbers indicate significance at 0.05 level.

The EC trends of two skeletal collections were further analyzed by feature to check that none of the differences were missed by pooling all features together. Likewise, testing by feature allowed differences between collections to be highlighted. Only the features showing significant differences were listed below (Table 3-11). All the features showing differences had higher frequencies of EC in the NILMFS skeletal collection than the UdeA skeletal collection, except for bone formation and erosion in zone 2 in the *biceps brachii* insertion. However, all the Cramer's V values were ≤0.3. The results differed from the GLM and Pearson Chi-squared test, with the stronger difference seen in the presence of FPO on the enthesis of the right CEO.

Table 3-11. Frequencies of EC presence by feature of the entheses showing significant difference between skeletal collections. Likelihood-Ratio test was chosen when the Pearson chi-squared test assumptions were violated.

			NILMFS			**UdeA**			**Pearson X^2**			
Enthesis	**Side**	**Feature**	**n**	***f***	**%**	**n**	***f***	**%**	**Value**	**df**	***p*-value**	**V / phi**
Subscapularis	Left	BF(Z2)	99	37	37%	66	15	23%	2.94	1	0.047	0.15
		MPO	99	12	12%	67	2	3%	4.32	1	0.038	0.16
Supraspinatus	Left	BF(Z2)	96	12	13%	61	1	2%	5.79	1	0.016	0.19
	Right	BF(Z1)	94	15	16%	56	2	4%	5.36	1	0.021	0.19
		FPO	95	15	16%	62	2	3%	6.13	1	0.016	0.20
Infraspinatus	Left	BF(Z2)	94	22	23%	52	5	10%	4.22	1	0.04	0.17
Common extensor	Left	BF(Z2)	93	30	32%	53	8	15%	5.17	1	0.023	0.19
	Right	TC	90	12	13%	63	2	3%	4.6	1	0.032	0.17
		FPO	90	15	17%	63	0	0%	11.64	1	0.001	0.28
Common flexor	Left	BF(Z2)	88	22	25%	52	4	8%	6.48	1	0.011	0.22
	Right	ER(Z2)	81	21	26%	57	5	9%	6.44	1	0.011	0.22
Biceps brachii	Right	TC	98	67	68%	67	31	46%	8.06	1	0.005	0.22
		BF(Z2)	98	18	18%	67	24	36%	6.39	1	0.011	0.20
		ER(Z2)	98	16	16%	67	24	36%	8.23	1	0.004	0.22
	Left	ER(Z2)	95	16	17%	66	21	32%	4.94	1	0.026	0.18

BF(Z1)= bone formation in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity.

3.2.1.2.2. Age range

The proportions of EC presence in each of the three age categories were compared by enthesis and skeletal collection (Table 3-12). The difference of EC presence within each of the three age ranges was not significant for the left or right side of any of the entheses analyzed, except for the left *biceps brachii* of the young adult group and the left *triceps brachii* of the old adult group. In the *biceps brachii*, 94% of the individuals from the UdeA skeletal collection presented EC, while 78% of young individuals from the NILMFS skeletal collection showed presence of EC. The Cramer’s V values were ≤0.3. The *triceps brachii* evidenced the opposite trend: the old individuals from the NILMFS collection (78%) had higher proportions than the UdeA skeletal collection (47%), with Cramer’s V value <0.4. However, after the Bonferroni correction neither difference was statistically significant.

Table 3-12. Comparison of the presence of EC between the two skeletal collections by age range. Results of Chi squared tests with Cramer's V value. Likelihood-Ratio test was used when Pearson's assumptions were violated.

			NILMFS			UdeA				Pearson Chi-square			Likelihood ratio			
Enthesis	**Side**	**Age range**	**n**	***f***	**%**	**n**	***f***	**%**	**N**	**Value**	**df**	***p*-value**	**Value**	**df**	***p*-value**	**V**
Subscapularis	Left	Young adult	36	15	42%	35	11	31%	71	0.80	1	0.371				0.11
		Middle adult	34	26	76%	19	10	53%	53	3.18	1	0.075				0.26
		Old adult	32	27	84%	15	14	93%	47				0.81	1	0.367	0.13
	Right	Young adult	36	20	56%	35	12	34%	71	3.24	1	0.072				0.21
		Middle adult	34	27	79%	19	16	84%	53				0.19	1	0.665	0.06
		Old adult	32	26	81%	15	13	87%	47				0.22	1	0.639	0.07
Supraspinatus	Left	Young adult	36	8	22%	35	6	17%	71	0.29	1	0.591				0.06
		Middle adult	34	13	38%	19	3	16%	53	2.91	1	0.088				0.23
		Old adult	32	20	63%	15	9	60%	47	0.03	1	0.869				0.02
	Right	Young adult	36	11	31%	35	8	23%	71	0.54	1	0.464				0.09
		Middle adult	34	12	35%	19	4	21%	53	1.17	1	0.279				0.15
		Old adult	32	21	66%	15	9	60%	47	0.14	1	0.708				0.06
Infraspinatus	Left	Young adult	36	12	33%	35	6	17%	71	2.46	1	0.117				0.19
		Middle adult	34	16	47%	19	5	26%	53	2.19	1	0.139				0.2
		Old adult	32	19	59%	15	6	40%	47	1.54	1	0.215				0.18
	Right	Young adult	36	7	19%	35	6	17%	71	0.06	1	0.802				0.03
		Middle adult	34	11	32%	19	3	16%	53	1.72	1	0.19				0.18
		Old adult	32	25	78%	15	10	67%	47				0.69	1	0.408	0.12
Common extensor	Left	Young adult	36	13	36%	35	7	20%	71	3.00	1	0.083				0.21
		Middle adult	34	19	56%	19	6	32%	53	0.05	1	0.82				0.03
		Old adult	32	24	75%	15	12	80%	47				0.89	1	0.347	0.13
	Right	Young adult	36	10	28%	35	4	11%	71	2.28	1	0.131				0.18
		Middle adult	34	19	56%	19	10	53%	53	2.89	1	0.089				0.23
		Old adult	32	24	75%	15	13	87%	47				0.15	1	0.703	0.06
Common flexor	Left	Young adult	36	3	8%	35	2	6%	71				0.19	1	0.665	0.05
		Middle adult	34	16	47%	19	4	21%	53	3.51	1	0.061				0.26
		Old adult	32	21	66%	15	8	53%	47	0.65	1	0.419				0.12
	Right	Young adult	36	8	22%	35	7	20%	71	0.05	1	0.819				0.03
		Middle adult	34	14	41%	19	6	32%	53	0.48	1	0.489				0.1
		Old adult	32	19	59%	15	8	53%	47	0.15	1	0.696				0.06
Biceps brachii	Left	Young adult	36	28	78%	35	33	94%	71				4.25	1	**0.039**	**0.24**
		Middle adult	34	33	97%	19	18	95%	53				0.17	1	0.677	0.06
		Old adult	32	30	94%	15	13	87%	47				0.62	1	0.423	0.12
	Right	Young adult	36	32	89%	35	27	77%	71	1.74	1	0.187				0.16
		Middle adult	34	33	97%	19	18	95%	53				0.17	1	0.677	0.06
		Old adult	32	30	94%	15	15	100%	47				1.58	1	0.209	0.14
Triceps brachii	Left	Young adult	36	17	47%	35	19	54%	71	0.35	1	0.552				0.07
		Middle adult	34	24	71%	19	15	79%	53	0.44	1	0.508				0.09
		Old adult	32	25	78%	15	7	47%	47				4.52	1	**0.034**	**0.32**
	Right	Young adult	36	18	50%	35	14	40%	71	0.72	1	0.397				0.1
		Middle adult	34	27	79%	19	16	84%	53				0.19	1	0.665	0.06
		Old adult	32	27	84%	15	11	73%	47				0.77	1	0.38	0.13

Bold numbers indicate significance at 0.05 level.

The differences between the two skeletal collections when age was considered were further analyzed by feature (Table 3-13). The results showed the opposite trend from the general trends, in which the UdeA collection had the higher presence of EC in most features, particularly in the young and middle adults. Except for the two features that were different among the young adults of the two skeletal collections, all the other features had medium effect size.

Table 3-13. Frequency, Pearson Chi-square, Fisher's exact test, Cramer's V and phi values comparing the EC trends of the two skeletal collections by feature.

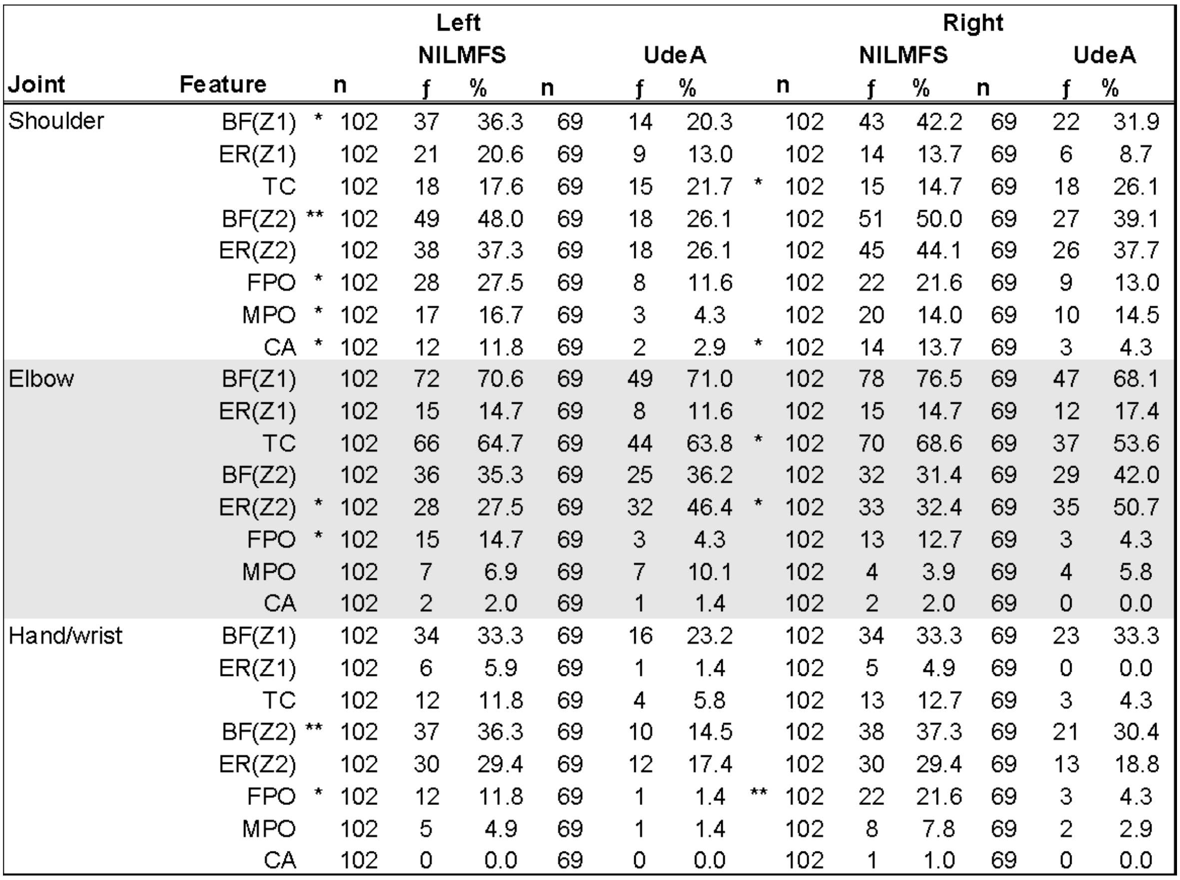
				NILMFS			UdeA			Pearson X^2				
Enthesis	**Side**	**Feature**	**Age range**	**n**	***f***	**%**	**n**	***f***	**%**	**Value**	**df**	***p*-value**	**Fisher's**	**V / phi**
Common extensor	Right	FPO	Old adult	28	8	29%	14	0	0%				0.04	**0.34**
Biceps brachii	Left	BF(Z1)	Young adult	34	13	38%	33	21	64%	4.32	1	0.038		0.25
		ER(Z2)	Middle adults	33	5	15%	18	9	50%				0.019	**0.37**
	Right	TC	Old adult	30	20	67%	15	4	27%	6.43	1	0.011		**0.38**
		BF(Z2)	Young adult	35	4	11%	33	12	36%	5.87	1	0.015		0.29
		ER(Z2)	Old adult	30	8	27%	15	10	67%	6.67	1	0.01		**0.39**
Triceps brachii	Right	ER(Z2)	Middle adults	31	5	16%	15	8	53%				0.014	**0.39**

Bold numbers indicate medium effect size.BF(Z1)= bone formation zone 1, TC= textural change, BF(Z2)= bone formation zone 2, ER(Z2)= erosion zone 2, FPO= fine porosity.

3.2.1.2.2.1. Joint complexes of the upper limbs

To test whether joint use was different between the individuals of the two collections, the frequencies of EC presence were pooled into the three major joints considering the main function of the muscle involved (see methods section). As evidenced in the EC trends by each collection, the proportions of EC presence by joint and side showed that most features (75%) were more frequent in the individuals from the NILMFS skeletal collection compared to the individuals of the UdeA skeletal collection (Table 3-14). Of those, 30.5% of the features showed a significant difference between collections, most of which were observed in the entheses of the left upper limbs (Table 3-15). However, all Cramer's V values were <0.3. Twenty-five percent (25%) of the remaining features evidence the opposite trend, in which the UdeA skeletal collection had higher proportions of EC presence. However, this difference was significant only for the presence of erosion (Z2) in both the right and the left elbow joint complex.

Table 3-14. Pooled frequencies of features by joint and side.



			Left							Right					
			NILMFS			UdeA				NILMFS			UdeA		
Joint	Feature		n	f	%	n	f	%		n	f	%	n	f	%
Shoulder	BF(Z1)	*	102	37	36.3	69	14	20.3		102	43	42.2	69	22	31.9
	ER(Z1)		102	21	20.6	69	9	13.0		102	14	13.7	69	6	8.7
	TC		102	18	17.6	69	15	21.7	*	102	15	14.7	69	18	26.1
	BF(Z2)	**	102	49	48.0	69	18	26.1		102	51	50.0	69	27	39.1
	ER(Z2)		102	38	37.3	69	18	26.1		102	45	44.1	69	26	37.7
	FPO	*	102	28	27.5	69	8	11.6		102	22	21.6	69	9	13.0
	MPO	*	102	17	16.7	69	3	4.3		102	20	14.0	69	10	14.5
	CA	*	102	12	11.8	69	2	2.9	*	102	14	13.7	69	3	4.3
Elbow	BF(Z1)		102	72	70.6	69	49	71.0		102	78	76.5	69	47	68.1
	ER(Z1)		102	15	14.7	69	8	11.6		102	15	14.7	69	12	17.4
	TC		102	66	64.7	69	44	63.8	*	102	70	68.6	69	37	53.6
	BF(Z2)		102	36	35.3	69	25	36.2		102	32	31.4	69	29	42.0
	ER(Z2)	*	102	28	27.5	69	32	46.4	*	102	33	32.4	69	35	50.7
	FPO	*	102	15	14.7	69	3	4.3		102	13	12.7	69	3	4.3
	MPO		102	7	6.9	69	7	10.1		102	4	3.9	69	4	5.8
	CA		102	2	2.0	69	1	1.4		102	2	2.0	69	0	0.0
Hand/wrist	BF(Z1)		102	34	33.3	69	16	23.2		102	34	33.3	69	23	33.3
	ER(Z1)		102	6	5.9	69	1	1.4		102	5	4.9	69	0	0.0
	TC		102	12	11.8	69	4	5.8		102	13	12.7	69	3	4.3
	BF(Z2)	**	102	37	36.3	69	10	14.5		102	38	37.3	69	21	30.4
	ER(Z2)		102	30	29.4	69	12	17.4		102	30	29.4	69	13	18.8
	FPO	*	102	12	11.8	69	1	1.4	**	102	22	21.6	69	3	4.3
	MPO		102	5	4.9	69	1	1.4		102	8	7.8	69	2	2.9
	CA		102	0	0.0	69	0	0.0		102	1	1.0	69	0	0.0

** Indicates significance at 0.05 level for Chi squared test. ** indicate significance at 0.01 level Chi squared test. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.*

Table 3-15. Chi-squared tests comparison of the two collections by feature and joint complex. Likelihood-Ratio test was used when Pearson's Chi-squared test assumptions were violated.

			Left				**Right**			
			Chi squared test				**Chi squared test**			
Joint	**Feature**	**N**	**Value**	**df**	***p*-value**	**V**	**Value**	**df**	***p*-value**	**V**
Shoulder	BF(Z1)	171	5.03	1	**0.025**	**0.17**	1.84	1	0.175	0.10
	ER(Z1)	171	1.62	1	0.203	0.10	1.01	1	0.315	0.08
	TC	171	0.44	1	0.506	0.05	3.42	1	0.064	0.14
	BF(Z2)	171	8.32	1	**0.004**	**0.22**	1.96	1	0.161	0.11
	ER(Z2)	171	2.33	1	0.127	0.12	0.70	1	0.402	0.06
	FPO	171	6.23	1	**0.013**	**0.19**	2.02	1	0.156	0.11
	MPO	171	6.05	1	**0.014**	**0.19**	0.74	1	0.388	0.07
Elbow	BF(Z1)	171	0.00	1	0.952	0.01	1.46	1	0.227	0.09
	ER(Z1)	171	0.34	1	0.558	0.05	0.22	1	0.637	0.04
	TC	171	0.02	1	0.900	0.01	3.96	1	**0.047**	**0.15**
	BF(Z2)	171	0.02	1	0.900	0.01	2.04	1	0.154	0.11
	ER(Z2)	171	6.47	1	**0.011**	**0.20**	5.80	1	**0.016**	**0.18**
	FPO	171	4.69	1	**0.030**	**0.17**	3.42	1	0.064	0.14
	MPO	171	0.59	1	0.442	0.06	0.32+	1	0.569	0.04

	CA+	171	0.06	1	0.800	0.02				
Wrist/hand	BF(Z1)	171	2.05	1	0.152	0.11	0.00	1	1.000	0.00
	ER(Z1)	171	2.06	1	0.151	0.11	3.48	1	0.620	0.14
	TC	171	1.73	1	0.189	0.10	3.42	1	0.064	0.14
	BF(Z2)	171	9.80	1	**0.002**	**0.24**	0.85	1	0.357	0.07
	ER(Z2)	171	3.21	1	0.073	0.14	2.44	1	0.118	0.12
	FPO	171	6.24	1	**0.013**	**0.19**	9.78	1	**0.002**	**0.24**
	MPO+	171	1.63	1	0.202	0.09	2	1	0.158	0.10
	CA+	171					1.04	1	0.308	0.06

Bold numbers indicated significance at 0.05 level. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation. + Indicates Likelihood-ratio test.

3.2.1.2.2.1.1. Shoulder

Both the GLM models with and without interactions showed the same results, in which age affected the presence of all the features of the left shoulder, except for textual change and fine porosity (Table 3-16). While the collection impacted the presence of bone formation (Z2) and fine porosity. The model with no interactions evidenced that macro-porosity was also affected by the collection. However, only fine porosity remained affected by the collection after the Bonferroni correction. On the right shoulder, the results of both models indicated the same trends as those observed in the left side, where age affected all the features, except for textural change and fine porosity. The GLM model without interactions showed that fine porosity was affected by age, but this trend was no longer significant after the Bonferroni correction. In contrast to the left side, the collection had no effect on any of the features.

The interaction of collection and age was significant for the bone formation (Z1) feature, but it ceased after the alpha value was adjusted using the Bonferroni test. The results of the Chi squared test (Table 3-17) showed that the difference highlighted by the GLM model was in the young adult group, where 38% of the individuals from the NILMFS had bone formation (Z1) on the right shoulder compared to 6% who showed the same feature in the UdeA collection. This trend remained significant after the Bonferroni correction. However, the Cramer’s V value was <0.3.

Table 3-16. Results of the GLM for the shoulder joint complex using age range and collection as predictors.

Shoulder	Side	Parameter	BF(Z1)	ER(Z1)	TC	BF(Z2)	ER(Z2)	FPO	MPO	CA	Overall
NILMFS	Left	N	102	102	102	102	102	102	102	102	102
		EC presence	37	21	18	49	38	28	17	12	77
		%	36%	21%	18%	48%	37%	27%	17%	12%	75%
UdeA		N	69	69	69	69	69	69	69	69	69
		EC presence	14	9	15	18	18	8	3	2	42
		%	20%	13%	22%	26%	26%	12%	4%	3%	61%
GLM model with interactions		AICC	32.173	28.842	32.167	32.664	33.319	31.717	-	-	-
		(Intercept)	0.000	0.000	0.000	0.01	0.000	0.000	-	-	-
		Collection	0.122	0.563	0.64	**0.026**	0.432	**0.01***	-	-	-
		Age	**<0.001***	**<0.001***	0.67	**<0.001***	**<0.001***	0.79	-	-	-
		Collection*Age	0.97	0.641	0.685	0.65	0.972	0.713	-	-	-
GLM model without interactions		AICC	27.963	25.459	28.653	29.255	29.104	28.122	22.425	-	29.912
		(Intercept)	0.000	0.000	0.000	0.01	0.000	0.000	0.000	-	0.000
		Collection	0.115	0.573	0.606	**0.026**	0.411	**0.011***	**0.033**	-	0.168
		Age	**<0.001***	**<0.001***	0.632	**<0.001***	**<0.001***	0.97	**<0.001***	-	**<0.001***
NILMFS	Right	N	102	102	102	102	102	102	102	102	102
		EC presence	43	14	15	51	45	22	20	14	80
		%	42%	14%	15%	50%	44%	22%	20%	14%	78%
UdeA		N	69	69	69	69	69	69	69	69	69
		EC presence	22	6	18	27	26	9	10	3	52
		%	32%	9%	26%	39%	38%	13%	14%	4%	75%
GLM model with interactions		AICC	33.14	-	31.912	33.914	34.123	31.532	30.189	-	31.334
		(Intercept)	0.017	-	0.000	0.553	0.132	0.000	0.000	-	0.000
		Collection	0.421	-	0.116	0.554	0.867	0.31	0.535	-	0.565
		Age	**<0.001***	-	0.174	**<0.001***	**<0.001***	0.106	**<0.001***	-	**<0.001***
		Collection*Age	**0.026**	-	0.857	0.954	0.69	0.675	0.251	-	0.508
GLM model without interactions		AICC	36.2	-	27.949	29.738	30.596	28.048	28.679	23.233	28.419
		(Intercept)	0.01	-	0.000	0.539	0.132	0.000	0.000	0.000	0.000
		Collection	0.536	-	0.12	0.556	0.931	0.265	0.825	0.085	0.901
		Age	**<0.001***	-	0.183	**<0.001***	**<0.001***	**0.027**	**<0.001***	**0.003***	**<0.001***

*Bold numbers indicated significance at 0.05 level. * Indicated significance at 0.05 after the Bonferroni correction. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.*

Table 3-17. Chi squared tests and Cramer's V comparing the proportions of presence of each feature in the shoulder joint complex between the two skeletal collections. Likelihood-Ratio test was used when Pearson's assumptions were violated.

					Left										Right						
					Pearson X^2			Likelihood ratio X^2							Pearson X^2			Likelihood ratio X^2			
Feature	**Age range**	**N**	**f**	**%**	**Value**	**df**	***p*-value**	**Value**	**df**	***p*-value**	**V**	**N**	**f**	**%**	**Value**	**df**	***p*-value**	**Value**	**df**	***p*-value**	**V**
BF(Z1)	Young adult	71	6	8%				0.68	1	0.409	0.1	71	12	17%	6.15	1	**0.013***				**0.29**
	Middle adult	53	16	30%	1.17	1	0.279				0.15	53	23	43%	0.19	1	0.663				0.06
	Old adult	47	29	62%	0.65	1	0.419				0.12	47	30	64%	0.86	1	0.353				0.14
ER(Z1)	Young adult	71	2	3%				0.00	1	0.984	0	71	0	0%	-	-	-	-			-
	Middle adult	53	6	11%				1.21	1	0.272	0.14	53	6	11%				0.02	1	0.891	0.02
	Old adult	47	22	47%	0	1	0.989				0	47	14	30%				0.10	1	0.747	0.05
TC	Young adult	71	16	23%	0.40	1	0.527				0.08	71	19	27%	0.77	1	0.381				0.1
	Middle adult	53	10	19%				0.19	1	0.665	0.06	53	7	13%				1.52	1	0.217	0.17
	Old adult	47	7	15%				0.44	1	0.509	0.1	47	7	15%				0.45	1	0.509	0.1
BF(Z2)	Young adult	71	9	13%				3.19	1	0.074	0.21	71	14	20%	0.29	1	0.591				0.06
	Middle adult	53	24	45%	2.25	1	0.134				0.21	53	34	64%	0.01	1	0.91				0.02
	Old adult	47	34	72%				0.35	1	0.555	0.09	47	30	64%	0.14	1	0.708				0.06
ER(Z2)	Young adult	71	9	13%				0.10	1	0.755	0.04	71	15	21%	0.05	1	0.819				0.03
	Middle adult	53	20	38%	0.48	1	0.489				0.1	53	25	47%	0.36	1	0.552				0.08
	Old adult	47	27	57%	0.15	1	0.697				0.06	47	31	66%	0.35	1	0.555				0.09
FPO	Young adult	71	14	20%	3.00	1	0.083				0.21	71	8	11%				0.51	1	0.476	0.08
	Middle adult	53	12	23%				0.83	1	0.363	0.12	53	8	15%				0.01	1	0.916	0.02
	Old adult	47	10	21%				3.28	1	0.07	0.24	47	15	32%				1.51	1	0.219	0.18
MPO	Young adult	71	1	1%				1.37	1	0.241	0.12	71	3	4%				0.33	1	0.568	0.07
	Middle adult	53	7	13%				1.85	1	0.174	0.18	53	10	19%				1.45	1	0.229	0.16
	Old adult	47	12	26%				1.87	1	0.171	0.19	47	17	36%	1.05	1	0.305				0.15
CA	Young adult	71	0	0%				-	-	-	-	71	2	3%				2.77	1	0.096	0.17
	Middle adult	53	6	11%				1.21	1	0.272	0.14	53	4	8%				0.23	1	0.629	0.07
	Old adult	47	8	17%				1.92	1	0.166	0.19	47	11	23%				1.34	1	0.247	0.16

*Bold numbers indicated significance at 0.05 level. * Indicated significance at 0.05 after the Bonferroni correction. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.*

3.2.1.2.2.1.2. Elbow

As described above the elbow showed the strongest differences between the two skeletal collections, before age was taken into consideration. When age is considered, the GLM models showed that age impacted bone formation (Z1) in the left and the right elbow (Table 3-18). Erosion in zone 2 in both the right and the left side evidenced a relationship with age in the GLM models with and without interactions. However, age remained significant after the Bonferroni correction only for the model with interactions on the right elbow. Both GLM models showed that the collection had a significant impact on the erosion (Z2) on the left and the right elbow, and fine porosity in the left elbow, but only for the model without interactions. Textural change on the left side, and erosion (Z2) on the right side, were affected by the interaction of collection and age. The trends observed for erosion (Z2), textural change, and fine porosity remained significant after adjusting the alpha value with the Bonferroni correction test.

Table 3-18. Results of the GLM for the elbow joint complex using age range and collection as predictors.

	Side	Parameter	BF(Z1)	ER(Z1)	TC	BF(Z2)	ER(Z2)	FPO	MPO	CA	Overall
NILMFS	Left	N	102	102	102	102	102	102	102	102	102
		EC presence	72	15	66	36	28	15	7	2	96
		%	71%	15%	65%	35%	27%	15%	7%	2%	94%
UdeA		N	69	69	69	69	69	69	69	69	69
		EC presence	49	8	44	25	32	3	7	1	66
		%	71%	12%	64%	36%	46%	4%	10%	1%	96%
GLM model with interactions		AICC	32.333	29.862	33.985	34.434	34.194	-	28.021	-	-
		(Intercept)	0.000	0.000	0.001	0.000	0.006	-	0.000	-	-
		Collection	0.91	0.589	0.822	0.892	**0.003***	-	0.287	-	-
		Age	**<0.001***	0.578	0.094	0.187	**0.045**	-	0.408	-	-
		Collection*Age	0.105	0.255	**0.01***	0.457	0.776	-	0.4	-	-
GLM model without interactions		AICC	32.56	28.322	38.849	31.73	-	23.308	25.583	-	24.343
		(Intercept)	0.000	0.000	0.000	0.001	-	0.000	0.000	-	0.000
		Collection	0.364	0.465	0.934	0.729	-	**0.014***	0.332	-	0.496
		Age	**<0.001***	0.436	0.384	0.169	-	0.338	0.331	-	0.203
NILMFS	Right	N	102	102	102	102	102	102	102	102	102
		EC presence	78	15	70	32	33	13	4	2	98
		%	76%	15%	69%	31%	32%	13%	4%	2%	96%
UdeA		N	69	69	69	69	69	69	69	69	69
		EC presence	47	12	37	29	35	3	4	0	63
		%	68%	17%	54%	42%	51%	4%	6%	0%	91%
GLM model with interactions		AICC	31.32	30.975	34.497	34.285	33.771	-	-	-	-
		(Intercept)	0.000	0.000	0.005	0.001	0.406	-	-	-	-
		Collection	0.362	0.62	**0.037**	0.156	**0.001***	-	-	-	-
		Age	**<0.001***	0.579	0.309	0.211	**0.011***	-	-	-	-
		Collection*Age	0.471	0.162	0.461	0.117	**0.008***	-	-	-	-
GLM model without interactions		AICC	28.556	30.346	31.775	34.298	39.068	24.285	21.219	-	-
		(Intercept)	0.000	0.000	0.002	0.002	0.062	0.000	0.000	-	-
		Collection	0.734	0.525	0.067	0.084	**0.008***	0.063	0.506	-	-
		Age	**<0.001***	0.559	0.278	0.098	**0.041**	0.591	0.272	-	-

*Bold numbers indicated significance. * Indicates significance after the Bonferroni correction. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.*

The Chi squared test was used to further understand the differences (Table 3-19). The left side showed that the young adult group of the UdeA skeletal collection had greater presence of bone formation (Z1) than the individuals from the NILMFS skeletal collection. The same was true for erosion (Z2) in the middle adult group. Presence of textural change in the old adult group evidenced the opposite trend, in which the proportions of the NILMFS skeletal collection were significantly greater that the proportions of textural change in the UdeA skeletal collection. Differences observed in the presence of textural change and erosion (Z2) had medium effect size. However, only the difference observed in the textural change remained significant after the Bonferroni correction.

Table 3-19. Chi squared tests and Cramer's V comparing the proportions of presence of each feature in the elbow joint complex between the two skeletal collections. Likelihood-Ratio test was used when Pearson's assumptions were violated.

					Left							**Right**									
					Pearson X^2			**Likelihood ratio X^2**							**Pearson X^2**			**Likelihood ratio X^2**			
Feature	**Age range**	**N**	**f**	**%**	**Value**	**df**	***p*-value**	**Value**	**df**	**value**	**V**	**N**	**f**	**%**	**Value**	**df**	**value**	**Value**	**df**	***p*-value**	**V**
BF(Z1)	Young adult	71	36	51%	4.08	1	**0.043**				**0.24**	71	35	49%	0.13	1	0.723				0.04
	Middle adult	53	43	81%				1.04	1	0.308	0.14	53	48	91%				1.33	1	0.248	0.16
	Old adult	47	42	89%				0.16	1	0.687	0.06	47	42	89%				0.16	1	0.687	0.06
ER(Z1)	Young adult	71	11	15%	0.08	1	0.782				0.03	71	9	13%				3.51	1	0.061	0.22
	Middle adult	53	8	15%				2.57	1	0.109	0.21	53	9	17%				0.03	1	0.862	0.02
	Old adult	47	4	9%				0.62	1	0.432	0.12	47	9	19%				0.51	1	0.477	0.1
TC	Young adult	71	44	62%	0.41	1	0.522				0.08	71	40	56%	0.12	1	0.731				0.04
	Middle adult	53	38	72%	2.29	1	0.131				0.21	53	38	72%	2.78	1	0.095				0.23
	Old adult	47	28	60%	6.30	1	**0.012***				**0.37**	47	29	62%	2.11	1	0.147				0.21
BF(Z2)	Young adult	71	22	31%	1.22	1	0.269				0.13	71	21	30%	5.84	1	**0.016***				**0.29**
	Middle adult	53	17	32%	0.45	1	0.502				0.09	53	18	34%	0.88	1	0.349				0.13
	Old adult	47	22	47%	0.00	1	0.989				0.00	47	22	47%	0.41	1	0.352				0.09
ER(Z2)	Young adult	71	19	27%	1.99	1	0.158				0.17	71	26	37%	0.16	1	0.687				0.05
	Middle adult	53	20	38%	5.12	1	**0.024**				**0.31**	53	17	32%	5.74	1	**0.017***				**0.33**
	Old adult	47	21	45%	2.09	1	0.148				0.21	47	25	53%	9.92	1	**0.002***				**0.46**
FPO	Young adult	71	9	13%				3.19	1	0.074	0.21	71	5	7%				1.97	1	0.16	0.16
	Middle adult	53	6	11%				1.21	1	0.272	0.14	53	7	13%				0.19	1	0.662	0.06
	Old adult	47	3	6%				2.40	1	0.121	0.18	47	4	9%				3.25	1	0.072	0.21
MPO	Young adult	71	4	6%				0.00	1	0.977	0.00	71	3	4%				0.39	1	0.535	0.07
	Middle adult	53	4	8%				2.77	1	0.096	0.23	53	1	2%				0.90	1	0.343	0.1
	Old adult	47	6	13%				0.01	1	0.937	0.01	47	4	9%				0.62	1	0.432	0.12
CA	Young adult	71	0	0%				-	-	-	-	71	0	0%				-	-	-	-
	Middle adult	53	0	0%				-	-	-	-	53	1	2%				0.90	1	0.343	0.1
	Old adult	47	3	6%				0.06	1	0.8	0.01	47	1	2%				0.78	1	0.377	0.1

*Bold numbers indicated significance at 0.05 level. * Indicated significance at 0.05 after the Bonferroni correction. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.*

On the right side, bone formation (Z2) in the young adult group and erosion (Z2) in the middle and old adult groups showed greater presence in the UdeA skeletal collection compared to the proportions of the NILMFS skeletal collection. The difference between skeletal collections of the three groups remained statistically significant after the Bonferroni corrections and the difference had a medium effect size.

3.2.1.2.2.1.3. Wrist/hand

As seen in the general trends, when age was not controlled for (Table 3-15) the left side of the hand/wrist joint complex showed that the proportions of EC presence observed in the NILMFS skeletal collection were higher than the proportions of EC presence in the UdeA skeletal collection in most of the features. The results of the GLM models confirmed that age affected the presence of bone formation in zones 1 and 2, and erosion (Z2) on the left wrist/hand (Table 3-20). While the collection had an impact on the presence of bone formation (Z2) and fine porosity on the entheses of the wrist/hand joint complex. On the right side, the GLM model with interactions was calculated only for the bone formation in zones 1 and 2, and the overall joint. The results of both features, BF(Z1) and BF(Z2) and the overall joint indicated that age affected them. The GLM model without interactions showed that age affected the presence of bone formation in zone 1 and 2, erosion in zone 2 and fine porosity. While the collection affected only the presence of fine porosity. All the trends observed in the left and the right wrist/hand complex remained significant after the Bonferroni correction, apart from the relationship between age and fine porosity in the right side.

The results of the Chi squared test showed that the difference between the two collections that was highlighted by the GLM model is the higher presence of bone formation (Z2) and fine porosity features on the left wrist/hand of the middle adults from the NILMFS collection (Table 3-21). Only the latter remained significant after the Bonferroni correction. On the right side the EC presence also tended to be greater in the NILMFS skeletal collection compared to the EC presence in the UdeA skeletal collection. The results of the Chi squared test indicated that the young adult category had statistically significant differences for the presence of textural change and erosion (Z2). Fine porosity was significant for both the middle and the old adult groups. Except for textural change, the difference between the two skeletal collections remained significant in all the other features after the Bonferroni correction with Cramer’s V values ranging from 0.27 to 0.32.

Table 3-20. Results of the GLM for the wrist/hand joint complex using age range and collection as predictors.

	Side	**Parameter**	**BF(Z1)**	**ER(Z1)**	**TC**	**BF(Z2)**	**ER(Z2)**	**FPO**	**MPO**	**CA**	**Overall**
NILMFS	Left	N	102	102	102	102	102	102	102	102	102
		EC presence	34	6	12	37	30	12	5	0	65
		%	33%	6%	12%	36%	29%	12%	5%	0%	64%
UdeA		N	69	69	69	69	69	69	69	69	69
		EC presence	16	1	4	10	12	1	1	0	29
		%	23%	1%	6%	14%	17%	1%	1%	0%	42%
GLM model with interactions		AICC	32.33	-	28.11	31.131	32.081	-	-	-	33.541
		(Intercept)	0.000	-	0.000	0.000	0.000	-	-	-	0.05
		Collection	0.609	-	0.27	0.008	0.203	-	-	-	0.089
		Age	**<0.001***	-	0.216	**<0.001***	**<0.001***	-	-	-	**<0.001***
		Collection*Age	0.861	-	0.922	0.574	0.631	-	-	-	0.577
GLM model without interactions		AICC	28.359	19.161	24	27.97	28.73	21.855	18.914	-	30.37
		(Intercept)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-	0.055
		Collection	0.524	0.119	0.28	**0.008***	0.214	**0.009***	0.231	-	**0.03**
		Age	**<0.001***	0.953	0.176	**<0.001***	**<0.001***	0.467	0.512	-	**<0.001***
NILMFS	Right	N	102	102	102	102	102	102	102	102	102
		EC presence	34	5	13	38	30	22	8	0	60
		%	33%	5%	13%	37%	29%	22%	8%	0%	59%
UdeA		N	69	69	69	69	69	69	69	69	69
		EC presence	23	0	3	21	13	3	2	0	34
		%	33%	0%	4%	30%	19%	4%	3%	0%	49%
GLM model with interactions		AICC	32.097	-	-	33.657	-	-	-	-	33.036
		(Intercept)	0.000	-	-	0.001	-	-	-	-	0.009
		Collection	0.115	-	-	0.843	-	-	-	-	0.659
		Age	**<0.001***	-	-	**<0.001***	-	-	-	-	**<0.001***
		Collection*Age	0.345	-	-	0.974	-	-	-	-	0.234
GLM model without interactions		AICC	29.955	-	25.393	29.438	32.459	26.548	22.175	-	31.667
		(Intercept)	0.000	-	0.000	0.001	0.000	0.000	0.000	-	0.022
		Collection	0.253	-	0.093	0.848	0.387	**0.002***	0.226	-	0.694
		Age	**<0.001***	-	0.201	**<0.001***	**<0.001***	**0.026**	0.424	-	**<0.001***

*Bold numbers indicated significance. * Indicated significance after the Bonferroni correction. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.*

Table 3-21. Chi squared tests and Cramer's V comparing the proportions of presence of each feature in the wrist/hand joint complex between the two skeletal collections. Likelihood-Ratio test was used when Pearson's assumptions were violated.

					Left							**Right**									
					Pearson X^2			**Likelihood ratio X^2**							**Pearson X^2**			**Likelihood ratio X^2**			
Feature	**Age range**	**N**	**f**	**%**	**Value**	**df**	***p*-value**	**Value**	**df**	**value**	**V**	**N**	**f**	**%**	**Value**	**df**	**value**	**Value**	**df**	***p*-value**	**V**
BF(Z1)	Young adult	71	6	8%				0.00	1	0.971	0.00	71	6	8%				3.28	1	0.07	0.21
	Middle adult	53	15	28%	0.06	1	0.81				0.03	53	21	40%	0.08	1	0.782				0.04
	Old adult	47	29	62%	0.65	1	0.421				0.12	47	30	64%	0.08	1	0.782				0.04
ER(Z1)	Young adult	71	3	4%				0.33	1	0.568	0.07	71	0	0%				-	-	-	-
	Middle adult	53	2	4%				1.82	1	0.177	0.15	53	3	6%				2.76	1	0.096	0.18
	Old adult	47	2	4%				1.58	1	0.209	0.14	47	2	4%				1.58	1	0.209	0.14
TC	Young adult	71	3	4%				0.33	1	0.568	0.07	71	3	4%				4.20	1	**0.04**	0.21
	Middle adult	53	7	13%				0.19	1	0.662	0.06	53	7	13%				1.85	1	0.174	0.18
	Old adult	47	6	13%				0.81	1	0.367	0.13	47	6	13%				0.01	1	0.937	0.01
BF(Z2)	Young adult	71	5	7%				1.97	1	0.16	0.16	71	11	15%	0.08	1	0.782				0.03
	Middle adult	53	15	28%	4.61	1	**0.032**				0.30	53	20	38%	0.01	1	0.92				0.02
	Old adult	47	27	57%	1.05	1	0.306				0.15	47	28	60%	0.00	1	0.968				0.01
ER(Z2)	Young adult	71	7	10%				1.38	1	0.248	0.14	71	5	7%				7.16	1	**0.007***	0.27
	Middle adult	53	11	21%				0.00	1	0.968	0.00	53	13	25%				0.20	1	0.658	0.06
	Old adult	47	24	51%	1.08	1	0.299				0.15	47	25	53%	0.41	1	0.522				0.09
FPO	Young adult	71	3	4%				0.33	1	0.568	0.07	71	5	7%				0.19	1	0.665	0.05
	Middle adult	53	6	11%				5.75	1	**0.017***	0.27	53	7	13%				7.80	1	**0.009***	0.29
	Old adult	47	4	9%				3.25	1	0.072	0.21	47	13	28%				5.75	1	**0.017***	0.32
MPO	Young adult	71	2	3%				0.00	1	0.984	0.00	71	2	3%				0.00	1	0.984	0.00
	Middle adult	53	1	2%				0.90	1	0.343	0.10	53	4	8%				0.23	1	0.629	0.07
	Old adult	47	3	6%				2.40	1	0.121	0.18	47	4	9%				3.25	1	0.072	0.21
CA	Young adult	71	0	0%				-	-	-	-	71	0	0%				1.372	1	0.241	0.12
	Middle adult	53	0	0%				-	-	-	-	53	0	0%				-	-	-	-
	Old adult	47	0	0%				-	-	-	-	47	0	0%				-	-	-	-

*Bold numbers indicated significance. * Indicated significance after the Bonferroni correction. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.*

3.2.1.2.3. Asymmetry

The trends of bilateral asymmetry observed in the entheses of the upper limbs were analyzed by subtracting the presence of EC in the left side minus the presence of EC in the right side (see methods section). In general, the overall frequencies of EC presence in the two skeletal collections showed that the majority of entheses had higher presence of EC in the left side than the right side. Only the *infraspinatus* and the common extensor entheses of the individuals from the NILMFS skeletal collection and the *biceps brachii* of the individuals from the UdeA skeletal collection evidenced the opposite trend, in which the right side had more overall presence compared to the left side (Table 3-22). The differences of the overall asymmetry trends between the two skeletal collections were not significant.

The frequencies by features showed that asymmetry was more frequent in the NILMFS skeletal collection than the UdeA skeletal collection. However, the Chi squared test indicated that the differences between the two collections were significant in only six times (13%): cavitation in the *subscapularis*, bone formation in zone 1 and zone 2 in the *supra,spinatus*, fine porosity in the common extensor, textural change in the *biceps brachii* and erosion (Z1) in the *triceps brachii*.

The *subscapularis* insertion evidenced that only the proportions of cavitation were different between the two skeletal collections. The same was true for bone formation in zone 1 and 2 of the *supraspinatus* enthesis, where the NILMFS skeletal collection had higher proportions of bone formation (Z1) in the left side (11.5%), while the UdeA skeletal collection had no individuals showing higher scores of bone formation in the left side. Bone formation (Z2) of the *supraspinatus* enthesis showed that the individuals from the NILMFS collection had more asymmetry in the right side than the individuals from the UdeA collection. The differences observed in the asymmetry of cavitation and bone formation (Z1) remained significant after the Bonferroni correction.

The proportions of asymmetry of fine porosity in the common extensor enthesis were different between the two skeletal collections, in which 11.9% of the individuals from the NILMFS collection and 0% of individuals from the UdeA collection had presence of fine porosity in the left side, but not the right side. The same was true in the *biceps brachii* enthesis, in which the textural change was only found in the left side of 13.8% individuals from the NILMFS skeletal collection and 4.7% individuals from the UdeA skeletal collection. The *biceps brachii* also presented textural change in the right side, but not the left side in 10.6% of individuals from the NILMFS collection and 21.9% of individuals from the UdeA skeletal collection.

Asymmetry in the *triceps brachii* enthesis was more frequent in the UdeA skeletal collection compared to the NILMFS collection. However, the chi-square results indicated that the only significant difference between the two collections was the asymmetry of the presence of erosion (Z1), in which 6.6% of the individuals from the NILMFS collection and 0% of the individuals from the UdeA collection reported presence of erosion only in the right side. The difference of asymmetry in the CEO remained significant after the Bonferroni correction. However, all the differences between the two collections had small effect size.

Table 3-22. Frequencies of asymmetry, Chi squared tests and Cramer's V of the entheses in the upper limbs by feature.

		Overall				**BF(Z1)**				**ER(Z1)**				**TC**				**BF(Z2)**				**ER(Z2)**				**FPO**				**MPO**				**CA**			
		NILMFS		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**	
Enthesis		*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**
Subscapularis	Left side higher	19	18.6	10	14.5	17	17.7	10	17.2	6	6.3	4	6.9	3	3.1	4	6.2	17	17.7	11	16.9	19	19.8	9	13.6	7	7.3	2	3.0	10	10.4	4	6.1	6	6.3	0	0.0
	Equal	69	67.6	55	79.7	65	67.7	46	79.3	78	81.3	50	86.2	86	89.6	56	86.2	66	68.8	48	73.8	70	72.9	55	83.3	81	84.4	63	95.5	78	81.3	61	92.4	83	86.5	66	100.0
	Right side higher	14	13.7	4	5.8	14	14.6	2	3.4	12	12.5	4	6.9	7	7.3	5	7.7	13	13.5	6	9.2	7	7.3	2	3.0	8	8.3	1	1.5	8	8.3	1	1.5	7	7.3	0	0.0
	Total	102		69		96		58		96		58		96		65		96		65		96		66		96		66		96		66		96		66	
	Chi-Square	3.70				5.00				1.22				**0.86**				0.77				2.69				**5.81**				4.70				**14.38**			
	df	2				2				2				2				2				2				2				2				2			
	p-value	0.157				0.082				0.543				0.651				0.682				0.261				0.055				0.095				0.001**			
	Cramer's V	0.15				0.18				0.09				0.07				0.07				0.13				0.18				0.17				0.25			
Supraspinatus	Left side higher	14	13.7	8	11.6	10	11.5	0	0.0	1	1.1	1	2.0	4	4.4	2	3.4	7	7.8	4	6.9	8	8.9	3	5.2	7	7.8	1	1.7	4	4.4	2	3.4	3	3.3	1	1.7
	Equal	77	75.5	56	81.2	75	86.2	49	98.0	80	92.0	45	90.0	82	91.1	52	89.7	77	85.6	54	93.1	75	83.3	52	89.7	76	84.4	54	93.1	83	92.2	56	96.6	86	95.6	57	98.3
	Right side higher	11	10.8	5	7.2	2	2.3	1	2.0	6	6.9	4	8.0	4	4.4	4	6.9	6	6.7	0	0.0	7	7.8	3	5.2	7	7.8	3	5.2	3	3.3	0	0.0	1	1.1	0	0.0
	Total	102		69		87		50		87		50		90		58		90		58		90		58		90		58		90		58		90		58	
	Chi-Square	0.87				**9.58**				**0.22**				**0.48**				**6.23**				**1.22**				**3.48**				**3.14**				**1.38**			
	df	2				2				2				2				2				2				2				2				2			
	p-value	0.649				0.008**				0.897				0.787				0.044*				0.544				0.176				0.208				0.501			
	Cramer's V	0.07				0.21				0.04				0.06				0.17				0.09				0.14				0.12				0.08			
Infraspinatus	Left side higher	15	14.7	12	17.4	3	3.4	1	2.3	0	0.0	0	0.0	5	5.6	3	6.7	7	7.9	1	2.2	10	11.2	2	4.4	4	4.5	3	6.7	2	2.2	3	6.7	1	1.1	0	0.0
	Equal	68	66.7	47	68.1	82	93.2	42	97.7	88	100.0	43	100.0	79	88.8	41	91.1	69	77.5	41	91.1	73	82.0	40	88.9	75	84.3	40	88.9	86	96.6	41	91.1	86	96.6	45	100.0
	Right side higher	19	18.6	10	14.5	3	3.4	0	0.0	0	0.0	0	0.0	5	5.6	1	2.2	13	14.6	3	6.7	6	6.7	3	6.7	10	11.2	2	4.4	1	1.1	1	2.2	2	2.2	0	0.0
	Total	102		69		88		43		88		43		89		45		89		45		89		45		89		45		89		45		89		45	
	Chi-Square	0.62				**2.57**				-				**0.94**				3.84				**1.90**				**2.07**				**1.78**				**2.49**			
	df	2				2				-				2				2				2				2				2				2			
	p-value	0.735				0.277				-				0.625				0.146				0.387				0.355				0.411				0.288			
	Cramer's V	0.06				0.11				-				0.08				0.17				0.11				0.12				0.12				0.11			

** Indicated significance at 0.05 level. ** indicated significance at 0.05 level after the Bonferroni correction. Bold numbers indicated that assumptions of the Pearson Chi squared test were violated, and Likelihood-ratio test was used. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.*

Continuation table 3-22. Frequencies of asymmetry, Chi squared tests and Cramer's V of the entheses in the upper limbs by feature.

		Overall				**BF(Z1)**				**ER(Z1)**				**TC**				**BF(Z2)**				**ER(Z2)**				**FPO**				**MPO**			
		NILMFS		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**	
Enthesis		***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**
Common extensor origin	Left side higher	17	16.7	9	13.0	6	7.2	6	13.0	3	3.6	0	0.0	6	7.1	1	2.0	8	9.5	6	11.8	10	11.9	2	3.9	10	11.9	0	0.0	7	8.3	1	2.0
	Equal	65	63.7	53	76.8	73	88.0	39	84.8	78	94.0	46	100.0	73	86.9	48	94.1	66	78.6	41	80.4	67	79.8	48	94.1	72	85.7	50	98.0	74	88.1	49	96.1
	Right side higher	20	19.6	7	10.1	4	4.8	1	2.2	2	2.4	0	0.0	5	6.0	2	3.9	10	11.9	4	7.8	7	8.3	1	2.0	2	2.4	1	2.0	3	3.6	1	2.0
	Total	102		69		83		46		83		46		84		51		84		51		84		51		84		51		84		51	
	Chi-Square	3.71				**1.65**				**4.52**				**2.34**				0.67				**5.89**				**10.04**				**3.08**			
	df	2				2				2				2				2				2				2				2			
	p-value	0.156				0.438				0.104				0.31				0.715				0.053				0.007**				0.215			
	Cramer's V	0.15				0.11				0.15				0.12				0.07				0.2				0.22				0.14			
Common flexor origin	Left side higher	15	14.7	11	15.9	7	9.6	3	6.1	0	0.0	0	0.0	3	3.8	0	0.0	11	14.1	8	16.7	14	17.9	3	6.3	7	9.0	2	4.2	0	0.0	1	2.1
	Equal	73	71.6	54	78.3	59	80.8	44	89.8	71	97.3	48	98.0	75	96.2	47	97.9	55	70.5	39	81.3	57	73.1	40	83.3	67	85.9	46	95.8	76	97.4	47	97.9
	Right side higher	14	13.7	4	5.8	7	9.6	2	4.1	2	2.7	1	2.0	0	0.0	1	2.1	12	15.4	1	2.1	7	9.0	5	10.4	4	5.1	0	0.0	2	2.6	0	0.0
	Total	102		69		73		49		73		49		78		48		78		48		78		48		78		48		78		48	
	Chi-Square	2.75				**2.03**				**0.06**				**4.82**				5.68				**3.84**				**5.20**				**3.85**			
	df	2				2				2				2				2				2				2				2			
	p-value	0.253				0.363				0.805				0.09				0.058				0.175				0.074				0.146			
	Cramer's V	0.13				0.13				0.02				0.17				0.21				0.17				0.17				0.15			
Biceps brachii	Left side higher	6	5.9	3	4.3	11	11.5	2	3.3	7	7.3	5	8.3	13	13.8	3	4.7	7	7.4	13	20.3	11	11.7	11	17.2	4	4.3	1	1.6	3	3.2	2	3.1
	Equal	94	92.2	59	85.5	77	80.2	51	85.0	82	85.4	53	88.3	71	75.5	47	73.4	75	79.8	43	67.2	72	76.6	45	70.3	88	93.6	61	95.3	86	91.5	60	93.8
	Right side higher	2	2.0	7	10.1	8	8.3	7	11.7	7	7.3	2	3.3	10	10.6	14	21.9	12	12.8	8	12.5	11	11.7	8	12.5	2	2.1	2	3.1	5	5.3	2	3.1
	Total	102		69		96		60		96		60		94		64		94		64		94		64		94		64		94		64	
	Chi-Square	**5.63**				3.46				**1.17**				6.33				5.79				1.05				**1.12**				**0.45**			
	df	2				2				2				2				2				2				2				2			
	p-value	0.06				0.178				0.556				0.042*				0.055				0.593				0.572				0.797			
	Cramer's V	0.18				0.15				0.08				0.2				0.19				0.08				0.08				0.05			
Triceps brachii	Left side higher	19	18.6	11	15.9	15	19.7	9	20.5	5	6.6	1	2.3	5	6.0	4	8.0	13	15.5	2	4.0	11	13.1	10	20.0	3	3.6	2	4.0	1	1.2	2	4.0
	Equal	70	68.6	47	68.1	58	76.3	31	70.5	66	86.8	43	97.7	74	88.1	41	82.0	59	70.2	41	82.0	68	81.0	32	64.0	73	86.9	47	94.0	82	97.6	44	88.0
	Right side higher	13	12.7	11	15.9	3	3.9	4	9.1	5	6.6	0	0.0	5	6.0	5	10.0	12	14.3	7	14.0	5	6.0	8	16.0	8	9.5	1	2.0	1	1.2	4	8.0
	Total	102		69		76		44		76		44		84		50		84		50		84		50		84		50		84		50	
	Chi-Square	0.47				**1.34**				**6.10**				**0.99**				4.27				5.42				**3.36**				5.19			
	df	2				2				2				2				2				2				2				2			
	p-value	0.79				0.511				0.047*				0.609				0.118				0.066				0.187				0.07			
	Cramer's V	0.05				0.11				0.19				0.09				0.18				0.2				0.15				0.2			

** Indicated significance at 0.05 level. ** indicated significance at 0.05 level after the Bonferroni correction. Bold numbers indicated that assumptions of the Pearson Chi squared test were violated, and Likelihood-ratio test was used. CA feature was excluded because no cases were recorded in either of the skeletal collections. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity.*

3.2.1.2.3.1. Asymmetry by age range

The overall asymmetry of the upper limb entheses within the three age categories showed different values and trends (Appendix 6). In general, the proportions of those without side asymmetry were lower in the NILMFS skeletal collection than the UdeA skeletal collection. However, when the asymmetries occurred the difference between the left-side proportions and the right-side proportions within the age ranges were higher in the UdeA skeletal collection than the NILMFS skeletal collection, e.g., the middle adult group of the *subscapularis* enthesis reported 17.6% individuals with left-side asymmetry and 14.7% individuals with right-side asymmetry, while the UdeA skeletal collection reported 31.6% in the left-side and 0 cases in the right-side asymmetry of the same enthesis. The results of the Likelihood-Ratio test showed that only the overall asymmetries in the young adult category of the *biceps brachii* were significantly higher in the UdeA than the NILMFS skeletal collections, with medium effect size (Table 3-23). This difference remained significant after the Bonferroni correction.

The comparison of the asymmetry proportions between the two skeletal collections by age ranges and features showed that the young adult group had significant differences in the asymmetries of bone formation (Z1) of the *biceps brachii* insertion and the erosion (Z2) of the *triceps brachii* insertion. The bilateral asymmetries of bone formation (Z1) were mostly found in the left side of the young adult individuals from the NILMFS skeletal collection (20.6% vs 0%). While the asymmetries of erosion (Z2) were more frequent in the right side of the young individuals from the UdeA skeletal collection (28% vs 3.3%). Both features had a medium effect size. Only the difference observed in the *biceps brachii* insertion remained significant after the Bonferroni correction.

The middle adult category showed significant differences in the textural change of the *biceps brachii* insertion and the erosion (Z2) of the *triceps brachii* insertion. The middle adult individuals from the UdeA skeletal collection showed higher values in both features. Textural change was most frequent in the right side (33.3 UdeA vs 6.3% NILMFS) and erosions (Z2) in the left side (35.7% UdeA vs 3.7% NILMFS). Both features had medium effect size. Only the difference observed in the *triceps brachii* remained significant after the Bonferroni correction.

Bone formation (Z2) in the common extensor origin was significantly more frequent in the left side of the old adult individuals from the UdeA skeletal collection (27.3%) than their equals from the NILMFS skeletal collection (3.8%). The difference showed a medium size effect, but it was no longer significant after the Bonferroni correction.

Table 3-23. Chi-squared, Cramer's V comparing asymmetry between the two skeletal collections by age ranges, features, and enthesis.

		Overall				**BF(Z1)**				**ER(Z1)**				**TC**				**BF(Z2)**				**ER(Z2)**				**FPO**				**MPO**				**CA**			
Enthesis	**Age range**	**X^2**	**df**	***p*-value**	**V**	**X^2**	**df**	***p*-value**	**V**	**X^2**	**df**	***p*-value**	**V**	**X^2**	**df**	***p*-value**	**V**	**X^2**	**df**	***p*-value**	**V**	**X^2**	**df**	***p*-value**	**V**	**X^2**	**df**	***p*-value**	**V**	**X^2**	**df**	***p*-value**	**V**	**X^2**	**df**	***p*-value**	**V**
Subscapularis	Young adult	4.15	2	0.125	0.24	10.58	2	**0.005***	0.35	0.02	2	0.889	0.02	0.40	2	0.82	0.08	1.99	2	0.37	0.17	0.75	2	0.688	0.11	5.80	2	0.055	0.25	2.84	2	0.092	0.18	2.84	2	0.092	0.18
	Middle adult	5.44	2	0.066	0.27	2.16	2	0.340	0.20	0.62	2	0.735	0.12	2.85	2	0.241	0.19	1.12	2	0.572	0.15	0.63	2	0.730	0.11	0.56	2	0.755	0.11	3.51	2	0.173	0.22	4.65	2	0.098	0.24
	Old Adult	2.94	2	0.230	0.21	4.26	2	0.119	0.32	0.90	2	0.638	0.14	1.83	2	0.401	0.21	3.92	2	0.141	0.30	2.11	2	0.348	0.18	5.32	2	0.07	0.28	1.14	2	0.567	0.15	5.32	2	0.07	0.28
Supraspinatus	Young adult	0.10	2	0.953	0.04	1.23	1	0.268	0.12	-	-	-	-	1.44	2	0.487	0.13	0.00	1	0.981	0.00	2.77	2	0.250	0.18	2.77	2	0.25	0.18	1.37	2	0.242	0.13	-	-	-	-
	Middle adult	0.55	2	0.759	0.1	2.11	1	0.146	0.18	2.11	2	0.348	0.18	0.34	2	0.845	0.09	3.84	2	0.147	0.26	4.00	2	0.135	0.24	1.65	2	0.438	0.15	2.33	2	0.312	0.18	-	-	-	-
	Old Adult	0.90	2	0.636	0.14	5.25	1	0.073	0.29	3.95	2	0.139	0.31	2.09	2	0.351	0.19	3.81	2	0.149	0.26	0.99	2	0.610	0.16	0.32	2	0.852	0.09	1.30	2	0.523	0.16	1.00	2	0.608	0.13
Infraspinatus	Young adult	1.49	2	0.474	0.14	-	-	-	-	-	-	-	-	0.24	2	0.889	0.07	0.15	2	0.927	0.05	1.12	2	0.571	0.12	1.83	2	0.4	0.18	1.82	1	0.177	0.17	-	-	-	-
	Middle adult	0.25	2	0.883	0.07	0.60	1	0.438	0.10	-	-	-	-	4.25	2	0.12	0.26	2.04	2	0.361	0.20	2.84	2	0.242	0.23	0.45	1	0.501	0.10	0.65	1	0.419	0.10	1.33	2	0.515	0.14
	Old Adult	1.04	2	0.594	0.15	2.32	2	0.314	0.19	-	-	-	-	0.37	1	0.544	0.10	4.97	2	0.083	0.30	1.27	2	0.531	0.17	0.26	1	0.61	0.08	2.37	2	0.305	0.26	0.72	1	0.395	0.11
Common extensor origin	Young adult	4.24	2	0.120	0.24	4.01	2	0.135	0.23	1.23	1	0.268	0.12	2.78	2	0.25	0.19	1.33	2	0.513	0.13	3.83	2	0.148	0.23	3.06	2	0.216	0.20	1.33	2	0.513	0.13	-	-	-	-
	Middle adult	2.59	2	0.274	0.21	1.67	2	0.433	0.17	1.33	1	0.25	0.14	0.08	2	0.961	0.04	5.87	2	0.053	0.30	0.33	1	0.565	0.09	3.15	1	0.076	0.22	0.08	1	0.783	0.04	-	-	-	-
	Old Adult	0.39	2	0.821	0.09	4.78	2	0.092	0.38	1.45	2	0.486	0.16	3.85	2	0.146	0.26	7.53	2	**0.023**	0.47	5.35	2	0.069	0.33	3.02	1	0.082	0.23	3.85	2	0.146	0.26	-	-	-	-
Common flexor origin	Young adult	1.49	2	0.475	0.14	1.49	2	0.476	0.14	0.00	1	0.959	0.01	-	-	-	-	1.27	2	0.531	0.13	2.49	2	0.287	0.18	0.02	1	0.896	0.02	1.60	1	0.206	0.15	-	-	-	-
	Middle adult	1.11	2	0.574	0.15	2.42	2	0.298	0.21	0.74	1	0.389	0.11	3.15	2	0.207	0.28	3.90	2	0.143	0.26	1.65	2	0.438	0.21	3.02	2	0.221	0.23	0.72	1	0.397	0.11	-	-	-	-
	Old Adult	0.99	2	0.610	0.14	4.11	2	0.128	0.32	-	-	-	-	1.81	1	0.179	0.19	2.07	2	0.355	0.24	0.59	2	0.743	0.13	2.24	2	0.326	0.23	0.89	1	0.346	0.13	-	-	-	-
Biceps brachii	Young adult	14.00	2	**0.001***	0.38	9.98	2	**0.007***	0.34	2.89	2	0.236	0.21	1.43	2	0.488	0.15	2.41	2	0.299	0.19	1.01	2	0.604	0.12	1.40	1	0.236	0.12	1.40	2	0.496	0.12	-	-	-	-
	Middle adult	0.36	2	0.834	0.08	1.77	2	0.412	0.15	0.43	2	0.806	0.10	6.15	2	**0.046**	0.37	4.30	2	0.117	0.30	2.79	2	0.247	0.24	0.18	2	0.916	0.06	-	-	-	-	0.90	1	0.342	0.11
	Old Adult	2.34	2	0.310	0.22	0.25	1	0.621	0.08	3.88	2	0.144	0.24	4.17	2	0.124	0.25	0.25	2	0.881	0.08	2.52	2	0.284	0.24	2.32	2	0.313	0.19	0.03	2	0.985	0.027	0.76	2	0.685	0.11
Triceps brachii	Young adult	1.94	2	0.379	0.16	6.76	2	0.034	0.32	1.25	2	0.264	0.13	2.27	2	0.321	0.20	0.10	2	0.951	0.04	7.97	2	**0.019**	0.37	3.04	2	0.218	0.22	4.94	2	0.085	0.26	-	-	-	-
	Middle adult	0.79	2	0.673	0.12	3.64	2	0.162	0.28	2.56	2	0.278	0.22	3.82	2	0.148	0.27	3.89	2	0.143	0.25	9.21	2	**0.01***	0.46	2.65	2	0.266	0.20	2.20	2	0.333	0.22	-	-	-	-
	Old Adult	2.78	2	0.249	0.25	4.11	2	0.128	0.34	3.83	2	0.147	0.27	3.31	2	0.143	0.30	5.42	2	0.067	0.30	1.42	2	0.492	0.20	1.41	2	0.494	0.15	2.55	1	0.111	0.26	-	-	-	-

*Bold indicates significance at 0.05 level. * Indicates significance at 0.05 level after the Bonferroni correction. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.*

3.2.1.2.3.2. Asymmetry by joint complexes

The frequencies of the overall asymmetry of the three joint complexes of the upper limbs showed that both collections had higher frequencies of EC in the left side than the right side (Table 3-24), except for the elbow in the UdeA skeletal collection and the wrist/hand complex in the NILMFS skeletal collection, in which the right side evidenced more presence of EC compared to the left side. However, the Chi squared test results showed that none of these trends were statistically different between the two skeletal collections.

The asymmetry by features evidenced that the individuals from the NILMFS skeletal collection had higher left-side asymmetry and right-side asymmetry of cavitations than those found in the individuals from the UdeA skeletal collection. The same was true for the proportions of the left-side asymmetry of the fine porosity features in the wrist/hand joint complex. However, the Cramer’s V values were <0.3.

Table 3-24. Frequencies of asymmetry, Chi squared test, and Cramer's V results of the joint complexes in the upper limb by feature.

		Overall				**BF(Z1)**				**ER(Z1)**				**TC**				**BF(Z2)**				**ER(Z2)**				**FPO**				**MPO**				**CA**			
Joint complex		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**	
		ƒ	**%**	**ƒ**	**%**	**ƒ**	**%**	**ƒ**	**%**	**ƒ**	**%**	**ƒ**	**%**	**ƒ**	**%**	**ƒ**	**%**	**ƒ**	**%**	**ƒ**	**%**	**ƒ**	**%**	**ƒ**	**%**	**ƒ**	**%**	**ƒ**	**%**	**ƒ**	**%**	**ƒ**	**%**	**ƒ**	**%**	**ƒ**	**%**
Shoulder	Left side higher	14	13.7	15	21.7	18	17.6	11	15.9	6	5.9	4	5.8	7	6.9	9	13.0	15	14.7	16	23.2	16	15.7	12	17.4	6	5.9	7	10.1	13	12.7	8	11.6	9	8.8	1	1.4
	Equal	77	75.5	49	71.0	72	70.6	55	79.7	83	81.4	58	84.1	85	83.3	54	78.3	74	72.5	46	66.7	77	75.5	53	76.8	84	82.4	56	81.2	79	77.5	60	87.0	86	84.3	68	98.6
	Right side higher	11	10.8	5	7.2	12	11.8	3	4.3	13	12.7	7	10.1	10	9.8	6	8.7	13	12.7	7	10.1	9	8.8	4	5.8	12	11.8	6	8.7	10	9.8	1	1.4	7	6.9	0	0.0
	Total	102		69		102		69		102		69		102		69		102		69		102		69		102		69		102		69		102		69	
	Chi-Square	2.22				3.11				0.27				1.87				2.07				0.58				1.36				4.97				**12.77**			
	df	2				2				2				2				2				2				2				2				2			
	p-value	0.329				0.211				0.872				0.394				0.354				0.749				0.507				0.083				0.002**			
	Cramer's V	0.11				0.14				0.04				0.1				0.11				0.06				0.09				0.17				0.24			
Elbow	Left side higher	4	3.9	2	2.9	13	12.7	6	8.7	12	11.8	6	8.7	13	12.7	8	11.6	16	15.7	11	15.9	19	18.6	13	18.8	5	4.9	3	4.3	4	3.9	3	4.3	2	2.0	0	0.0
	Equal	96	94.1	62	89.9	82	80.4	55	79.7	78	76.5	61	88.4	80	78.4	46	66.7	66	64.7	51	73.9	69	67.6	46	66.7	90	88.2	63	91.3	91	89.2	60	87.0	98	96.1	68	98.6
	Right side higher	2	2.0	5	7.2	7	6.9	8	11.6	12	11.8	2	2.9	9	8.8	15	21.7	20	19.6	7	10.1	14	13.7	10	14.5	7	6.9	3	4.3	7	6.9	6	8.7	2	2.0	1	1.4
	Total	102		69		102		69		102		69		102		69		102		69		102		69		102		69		102		69		102		69	
	Chi-Square	**2.97**				1.66				5.04				5.71				2.85				0.02				**0.53**				**0.22**				**2.16**			
	df	2				2				2				2				2				2				2				2				2			
	p-value	0.226				0.436				0.08				0.058				0.241				0.988				0.766				0.895				0.34			
	Cramer's V	0.13				0.1				0.17				0.18				0.13				0.01				0.06				0.04				0.09			
Wrist/hand	Left side higher	18	17.6	13	18.8	8	7.8	11	15.9	3	2.9	0	0.0	8	7.8	1	1.4	14	13.7	14	20.3	13	12.7	6	8.7	15	14.7	3	4.3	8	7.8	2	2.9	0	0.0	0	0.0
	Equal	61	59.8	48	69.6	86	84.3	54	78.3	95	93.1	68	98.6	87	85.3	66	95.7	75	73.5	52	75.4	76	74.5	58	84.1	82	80.4	65	94.2	89	87.3	66	95.7	101	99.0	69	100.0
	Right side higher	23	22.5	8	11.6	8	7.8	4	5.8	4	3.9	1	1.4	7	6.9	2	2.9	13	12.7	3	4.3	13	12.7	5	7.2	5	4.9	1	1.4	5	4.9	1	1.4	1	1.0	0	0.0
	Total	102		69		102		69		102		69		102		69		102		69		102		69		102		69		102		69		102		69	
	Chi-Square	3.37				2.86				**4.17**				**5.62**				4.20				**2.27**				**7.21**				**3.78**				**1.04**			
	df	2				2				2				2				2				2				2				2				1			
	p-value	0.185				0.239				0.221				0.06				0.122				0.322				0.027*				0.151				0.308			
	Cramer's V	0.14				0.13				0.13				0.17				0.16				0.12				0.2				0.14				0.06			

* Indicates significance at 0.05 level. Bold numbers indicate that assumptions of the Pearson Chi squared test were violated, and Likelihood-ratio was used. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.

3.2.1.2.3.3. Asymmetry by joint complexes and age range

The frequencies of bilateral asymmetries observed in all features of the joint complexes within the three age categories were compared between the two skeletal collections (Appendix 7). The proportions of bilateral asymmetry of most of the features (91.5%) were similar in the three joint complexes of the individuals from both skeletal collections (Table 3-25). The results of the Likelihood-Ratio test evidenced that only two asymmetries of the shoulder joint were significantly different between the two collections. The left-side asymmetry of the bone formation (Z1) was more frequent in the young adults from the NILMFS compared to the young adults from the UdeA collection. The middle adults from the UdeA skeletal collection showed that the proportions of individuals without side asymmetry were significantly lower than those observed in the individuals from the same age category in the NILMFS skeletal collection. The differences had medium effect size. However, the trends were no longer significant after the Bonferroni correction.

The asymmetries observed in the elbow indicated that the overall EC proportions were higher in the right side of the young adults from the UdeA skeletal collection than the young adults from the NILMFS skeletal collection. However, the effect size was small, and this trend ceased to be significant after the Bonferroni correction. Textural change was more common in the right side of the middle adult individuals from the UdeA skeletal collection than the individuals of the same age category from the NILMFS skeletal collection. The opposite trend was observed in the proportions of the erosion (Z1) feature, in which the old adults from the NILMFS skeletal collection evidenced more left-side asymmetry than the old adults from the UdeA skeletal collection. The trends of the textural change and erosion (Z1) features had medium effect size, but only the difference of asymmetry observed in textural change remained significant after the Bonferroni correction.

The wrist and hand joint complex showed that the proportions of overall asymmetry and the proportions of each feature had no significant differences between the two skeletal collections.

Table 3-25. Likelihood-Ratio test, and Cramer's V results comparing asymmetry between both skeletal collections by joint complexes in the upper limbs.

Joint			overall	BF(Z1)	ER(Z1)	TC	BF(Z2)	ER(Z2)	FPO	MPO	CA
Shoulder	Young adult	Chi-squared	0.463	7.356	0	0.969	1.281	0.454	2.716	1.727	2.773
		df	2	2	1	2	2	2	2	2	1
		p-value	0.793	**0.025**	0.984	0.616	0.527	0.797	0.257	0.422	0.096
		Cramer's V	0.08	0.31	0	0.12	0.13	0.08	0.18	0.14	0.17
	Middle adult	Chi-squared	2.776	2.57	0.67	2.063	1.362	1.044	2.865	6.064	5.748
		df	2	2	2	2	2	2	2	2	2
		p-value	0.25	0.277	0.715	0.357	0.506	0.593	0.239	**0.048**	0.056
		Cramer's V	0.23	0.21	0.11	0.19	0.16	0.14	0.24	0.29	0.27
	Old adult	Chi-squared	1.579	5.561	0.65	1.374	0.193	0.31	0.145	3.505	3.442
		df	2	2	2	2	2	2	2	2	2
		p-value	0.454	0.062	0.723	0.503	0.908	0.857	0.93	0.173	0.179
		Cramer's V	0.14	0.36	0.04	0.18	0.07	0.08	0.06	0.28	0.23
Elbow	Young adult	Chi-squared	7.12	4.525	3.96	2.087	1.217	2.016	0.681	0.388	-
		df	2	2	2	2	2	2	2	2	-
		p-value	**0.028**	0.104	0.138	0.352	0.544	0.365	0.711	0.824	-
		Cramer's V	**0.28**	0.24	0.23	0.17	0.13	0.17	0.1	0.07	-
	Middle adult	Chi-squared	2.086	0.018	1.277	8.221	2.662	2.48	0.365	3.566	0.899
		df	1	2	2	2	2	2	2	2	1
		p-value	0.149	0.991	0.528	**0.016***	0.264	0.289	0.833	0.168	0.343
		Cramer's V	0.19	0.02	0.15	**0.4**	0.21	0.22	0.09	0.25	0.1
	Old adult	Chi-squared	1.049	1.374	7.883	1.228	2.459	5.949	2.401	0.394	0.78
		df	2	2	2	2	2	2	2	2	2
		p-value	0.592	0.503	**0.019**	0.541	0.292	0.051	0.301	0.821	0.677
		Cramer's V	0.13	0.18	**0.33**	0.16	0.22	0.29	0.18	0.09	0.1
Wrist/hand	Young adult	Chi-squared	4.903	2.095	0.326	2.773	1.05	4.489	0.543	0.001	-
		df	2	2	1	2	2	2	2	2	-
		p-value	0.086	0.351	0.568	0.25	0.592	0.106	0.762	1	-
		Cramer's V	0.26	0.17	0.07	0.17	0.12	0.22	0.09	0	-
	Middle adult	Chi-squared	0.192	1.617	2.763	4.1	2.857	0.179	4.726	1.161	-
		df	2	2	2	2	2	2	2	2	-
		p-value	0.909	0.446	0.251	0.129	0.24	0.914	0.094	0.56	-
		Cramer's V	0.06	0.18	0.18	0.23	0.22	0.06	0.24	0.12	-
	Old adult	Chi-squared	3.672	1.909	1.579	3.446	1.909	5.156	4.25	5.94	-
		df	2	2	2	2	2	2	2	2	-
		p-value	0.159	0.385	0.454	0.179	0.385	0.076	0.119	0.051	-
		Cramer's V	0.23	0.21	0.14	0.22	0.21	0.27	0.27	0.29	-

*Bold indicated significance at 0.05 level. * Indicated significance at 0.05 after the Bonferroni correction. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.*

The results of the upper limbs were consistent with previous studies in which bone formation was the most frequent feature in both skeletal collections and was associated with aging. While fine porosity and textural change were more common amongst young individuals. When comparing the prevalence of the two skeletal collections, it was noticed that fine porosity and textural change were more frequent in the left arm of individuals from the NILMFS collection, while erosions were common in the elbows of middle and old adults from the UdeA skeletal collection.

3.2.2. Lower limbs

3.2.2.1. *Descriptive and inferential statistics*

3.2.2.1.1. University of Antioquia -UdeA skeletal collection

The frequencies of EC presence in the seven entheses of the lower limbs showed that the percentage of cases that could be recorded ranged from 78% to 97%. The average of observable cases in zone 1 was 86% and SD 5%, and the observable cases in zone 2 was 88% and SD 6% (Appendix 8). The gastrocnemius origin in both, the right and left side, (96% of observable cases in zone 1 and 97% in zone 2), was the most observable enthesis of all the entheses in the lower limbs. Most missing cases were found in both the left and the right side of the *vastus lateralis* enthesis (96% of observable cases ranging from 78% to 80% in zone 1 and 78% to 81% in zone 2). Except for the *vastus lateralis* enthesis of the left patella, all entheses showed higher sample size in zone 2 than in zone 1.

General trends of score “1” indicate that bone formation (Z1) (left 41%, right 43%) and textural change (left 36%, right 33%) were the most frequent features overall, followed by bone formation (left 21%, right 18%) and erosion (left 16%, right 11%) in zone 2. Erosion (Z1) (left 3%, right 2%), fine porosity (left 3%, right 3%), and macro-porosity (left 2%, right 1%) features showed a minor presence in the overall frequencies. No cavitation was found in the lower limbs.

All entheses showed high frequencies of bone formation (Z1) in both anatomical sides (mean 24.9%, and SD 13.8%), except for the iliopsoas and the gastrocnemius origin, in which the presence of bone formation ranged between 7.2% and 13%. The frequencies of score 1 of the *triceps surae* insertion showed that bone formation in both zone 1 (left 68%, right 71%) and zone 2 (left 35%, right 39%) had the highest frequencies among all entheses. Frequencies of textural change were similar within all entheses with an average presence of 20.9%, and SD 8.1%, except for both sides of the *vastus lateralis* insertion (left 51%; right 54%) in which the percentages of textural change were greater than average. Erosion (Z2) evidenced the highest frequencies of score 1 in both sides of the iliopsoas insertion (left 34.8%; right 24.6%), the gastrocnemius origin (left 20.3%; right 10.1%), and the *quadriceps femoris* insertion (left 17.4%; right 15.9%). While erosion in zone 1 evidenced low frequencies in all entheses, an average of 2.8%, and SD 3.1%, except for the *quadriceps femoris* of the left patella (14.5%) where the presence of EC score “1” was greater than the average. The plantar fascia origin (left 35%; right 42%) showed high presence of bone formation in both sides. No erosion was recorded in this enthesis.

Score “2” was rarely recorded in any of the features. Erosion (Z2) had more than one case of score 2 in both sides of the *vastus lateralis* (4.3%). The same was true for bone formation (Z1) in both the right and the left sides of the patellar ligament (2.9%), and the right plantar fascia (4.3%) entheses. Only the latter enthesis showed higher frequencies on the right side than on the left side. Only 1 case of score 2 was found in the lower limbs, left iliopsoas. Similar to the NILMFS collection, the lower limbs show no cavitations reaching the criteria for score 2.

The results of the pooled frequencies in the lower limbs i.e. present (scores 1 and 2) and absent (score 0) categories, were consistent with those observed in score “1”, in which bone formation (Z1) evidenced the highest frequencies of all features in both the left (44%) and the right side (42%) (Table 3-26), followed by the presence of textural change in both anatomical sides (left 36%, right 33%), the presence of bone formation (Z2) in both the left (22%) and the right side (18%), and erosion (Z2) in both sides (left 13%, right 18%). Erosion (Z1), fine porosity, and macro-porosity evidenced overall presence under 3% in both sides. In general, the presence of EC in the left side was higher than the presence in the right side in all features, except for the bone formation in zone 1.

The presence of EC within each of the three age ranges showed that the trends change from enthesis to enthesis, however bone formation is consistently more frequent in the older adults (Appendix 9). The results of Likelihood-Ratio test and Cramer’s V by age groups, features and entheses showed that the difference observed between the three age ranges in the presence of bone formation in both zone 1 and zone 2 were significant in the majority of the entheses, with the old adult and the middle adult (in that order) being the groups with the highest frequencies of all (Table 3-27). Nine out of fourteen entheses (64%) had significant differences in the presence of BF(Z1) within the three different age groups; while bone formation (Z2) showed that six out of twelve entheses (50%) were significantly different within the age groups. The same was true for textural change and erosion (Z2) in only one enthesis. All differences showed Cramer's V values between 0.3 and 0.5. No other feature showed significant differences between the age groups.

The *triceps surae* origin was the only enthesis showing that the presence of bone formation in zones 1 and 2 is bilaterally different between the three age groups. Cramer's V values ranged from 0.37 to 0.55. The presence of bone formation in both zone 1 and 2 of the patellar ligament insertion on the left side was also different between the three age ranges, with lower Cramer's V values than the *triceps surae* origin. However, the same enthesis showed significant differences in the presence of bone formation (Z2) in the left, but not the right side, with slightly higher Cramer's V value than the *triceps surae* origin. The right iliopsoas enthesis showed a difference, in the presence of bone formation (Z1), and erosion (Z2). These two features were mostly observed in the old adult group. The Likelihood-Ratio test results evidenced that bone formation (Z1) of both sides, and textural change in the right side of the *vastus lateralis* insertion, had significant differences between the three age groups, with Cramer's V values >0.3

Table 3-26. Frequencies of EC presence by side and by enthesis in the lower limbs of the UdeA skeletal collection.

		BF(Z1)			**ER (Z1)**			**TC**			**BF(Z2)**			**ER (Z2)**			**FPO**			**MPO**			**CA**			**Variability**		
Side	**Enthesis**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**
Left	Gastrocnemius	66	5	8%	66	0	0%	67	27	40%	67	7	10%	67	15	22%	67	0	0%	67	1	1%	67	0	0%	534	55	10%
	Iliopsoas	59	9	15%	59	0	0%	61	17	28%	61	12	20%	61	25	41%	61	3	5%	61	2	3%	61	0	0%	484	68	14%
	Patellar ligament	58	30	52%	58	0	0%	61	15	25%	61	13	21%	61	4	7%	61	4	7%	61	1	2%	61	0	0%	482	67	14%
	Plantar fascia	59	25	42%	58	0	0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	117	25	21%
	Quadriceps femoris	60	32	53%	60	10	17%	60	18	30%	60	19	32%	60	13	22%	60	1	2%	60	1	2%	60	0	0%	480	94	20%
	Triceps surae	61	48	79%	61	0	0%	64	19	30%	64	24	38%	64	5	8%	64	2	3%	64	2	3%	64	0	0%	506	100	20%
	Vastus lateralis	55	27	49%	55	3	5%	54	35	65%	54	4	7%	54	4	7%	54	1	2%	54	0	0%	54	0	0%	434	74	17%
	Total	418	176	42%	417	13	3%	367	131	36%	367	79	22%	367	66	18%	367	11	3%	367	7	2%	367	0	0%	3037	483	16%
Right	Gastrocnemius	66	6	9%	66	1	2%	67	21	31%	67	4	6%	67	7	10%	67	3	4%	67	1	1%	67	0	0%	534	43	8%
	Iliopsoas	62	8	13%	62	1	2%	62	16	26%	62	9	15%	62	18	29%	62	3	5%	62	2	3%	62	0	0%	496	57	11%
	Patellar ligament	58	29	50%	58	2	3%	58	13	22%	58	6	10%	58	2	3%	58	3	5%	58	0	0%	58	0	0%	464	55	12%
	Plantar fascia	59	32	54%	59	0	0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	118	32	27%
	Quadriceps femoris	58	32	55%	58	4	7%	59	21	36%	59	15	25%	59	11	19%	59	0	0%	59	0	0%	59	0	0%	470	83	18%
	Triceps surae	60	50	83%	60	1	2%	60	12	20%	60	27	45%	60	1	2%	60	3	5%	60	0	0%	60	0	0%	480	94	20%
	Vastus lateralis	54	27	50%	54	2	4%	56	36	64%	56	4	7%	56	7	13%	56	0	0%	56	0	0%	56	0	0%	444	76	17%
	Total	417	184	44%	417	11	3%	362	119	33%	362	65	18%	362	46	13%	362	12	3%	362	3	1%	362	0	0%	3006	440	15%

BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.

Table 3-27. Results of Likelihood-Ratio test and Cramer's V comparing EC presence between the three age ranges. Entheses of the lower limbs, UdeA skeletal collection.

	Left							Right						
Enthesis	**BF (Z1)**	**ER(Z1)**	**TC**	**BF(Z2)**	**ER(Z2)**	**FPO**	**MPO**	**BF (Z1)**	**ER(Z1)**	**TC**	**BF(Z2)**	**ER(Z2)**	**FPO**	**MPO**
Gastrocnemius														
N	66	66	67	67	67	67	67	66	66	67	67	67	67	67
X^2	6.16	NaN	0.16	1.60	3.87	NaN	1.37	5.09	2.64	4.70	12.91	3.24	4.21	1.37
df	2		2	2	2		2	2	2	2	2	2	2	2
p-value	**0.046**		0.923	0.451	0.144		0.504	0.078	0.27	0.095	**0.002**	0.198	0.122	0.504
Cramer's V	**0.31**		0.05	0.15	0.25		0.12	0.25	0.20	0.27	**0.47**	0.23	0.21	0.12
Iliopsoas														
N	59	59	61	61	61	61	61	62	62	62	62	62	62	62
X^2	4.12	NaN	1.40	2.67	3.41	3.82	2.52	13.53	3.03	5.51	5.70	6.78	3.92	1.50
df	2		2	2	2	2	2	2	2	2	2	2	2	2
p-value	0.127		0.497	0.263	0.182	0.148	0.284	**0.001**	0.219	0.064	0.058	**0.034**	0.141	0.472
Cramer's V	0.26		0.16	0.21	0.24	0.21	0.17	**0.41**	0.24	0.31	0.32	**0.33**	0.21	0.14
Patella ligament														
N	58	58	61	61	61	61	61	58	58	58	58	58	58	58
X^2	8.64	NaN	3.75	8.64	1.73	1.43	1.37	4.21	2.58	1.80	9.77	1.57	2.93	NaN
df	2		2	2	2	2	2	2	2	2	2	2	2	
p-value	**0.013**		0.153	**0.013**	0.421	0.489	0.504	0.122	0.277	0.416	**0.008**	0.457	0.231	
Cramer's V	**0.38**		0.25	**0.39**	0.18	0.16	0.13	0.27	0.18	0.18	**0.38**	0.14	0.21	
Plantar fascia														
N	69	69	0	0	0	0	0	69	59					
X^2	3.09	NaN	NaN	NaN	NaN	NaN	NaN	10.15	NaN					
df	2							2						
p-value	0.213							**0.006**						
Cramer's V	0.21							**0.38**						
Quadriceps femoris														
N	60	60	60	60	60	60	60	58	58	59	59	59	59	59
X^2	0.34	0.79	0.78	6.91	0.41	1.40	3.12	7.52	0.10	3.10	1.72	0.65	NaN	NaN
df	2	2	2	2	2	2	2	2	2	2	2	2		
p-value	0.843	0.672	0.678	**0.032**	0.815	0.496	0.21	**0.023**	0.953	0.21	0.423	0.722		
Cramer's V	0.08	0.12	0.11	**0.34**	0.08	0.13	0.25	**0.36**	0.04	0.22	0.17	0.10		
Triceps surae														
N	61	61	64	64	64	64	64	60	60	60	60	60	60	60
X^2	14.47	NaN	1.23	20.24	3.21	1.36	2.71	11.56	2.82	0.61	8.50	2.82	4.69	NaN
df	2		2	2	2	2	2	2	2	2	2	2	2	
p-value	**0.001**		0.541	**< .001**	0.201	0.508	0.258	**0.003**	0.244	0.739	**0.014**	0.244	0.096	
Cramer's V	**0.44**		0.14	**0.55**	0.18	0.13	0.17	**0.39**	0.23	0.10	**0.37**	0.23	0.25	
Vastus lateralis														
N	55	55	54	54	54	54	54	54	54	56	56	56	56	56
X^2	6.46	1.55	4.75	1.75	2.36	1.48	NaN	9.59	2.28	6.14	4.97	3.03	NaN	NaN
df	2	2	2	2	2	2		2	2	2	2	2		
p-value	**0.04**	0.462	0.093	0.418	0.307	0.477		**0.008**	0.32	**0.046**	0.083	0.22		
Cramer's V	**0.34**	0.13	0.30	0.19	0.17	0.14		**0.41**	0.17	**0.34**	0.31	0.18		

Bold numbers indicated significance at 0.05 level. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.

3.2.2.1.2. National Institute of Legal Medicine and Forensic Sciences – NILMFS skeletal collection

The preservation of the bones in the lower limbs allowed observation of the entheseal surface similar to the UdeA skeletal collection, ranging from 78.4% to 96% depending on the enthesis. The zone 1 was slightly more recordable in this collection than the UdeA, on average 90%, SD

5%, while zone 2 was recorded on average 88%, SD 5% (Appendix 10). The most observable entheses were the two located in the calcaneus, i.e., the *triceps surae* and the plantar fascia, which were observed in 89% and 96% of individuals. The entheses with most cases that could not be recorded were the *vastus lateralis* and the *quadriceps femoris*, both entheses located in the patella, with observability ranging from 78% to 87%. All entheses of the lower limbs showed either equal or higher sample size in zone 1 than zone 2.

General trends of score "1" in the lower limbs showed that bone formation in zone 1 was the most frequent feature overall (mean 36.1%, SD 19.8; median 38.7%), followed by textural change (mean 22.9%, SD 16.7; median 21.1%), and bone formation in zone 2 (mean 16%, SD 9.75; median 16.7%). Of these, bone formation (Z1) had the highest frequencies of score 1 in all entheses, except for the iliopsoas insertion, and the gastrocnemius in both lower limbs, and the right *vastus lateralis* insertion, in which textural change was the most frequent feature. Erosion in zone 1 (mean 4.2%, SD 3.3; median 3.4%) and fine porosity (mean 4.6%, SD 4.6; median 2.9%) showed similar mean and median values; and excluding the *vastus lateralis* insertion, both features were present in all the entheses. Erosion (Z1) had the highest frequencies on the patellar ligament insertion in both sides while fine porosity was more frequent in the *triceps surae* insertion of both limbs and the left patellar ligament. Erosion in zone 2 (mean 9.1%, SD 8.6; median 6.4%) was more frequently reported in the iliopsoas and gastrocnemius entheses than any other enthesis. Cavitations (mean 0.1%, SD 0.4; median 0%) and macro-porosity (mean 1.5%, SD 2.2; median 0.5%) were the least frequent features.

The gastrocnemius origin evidenced low frequencies in all features except in the erosion of zone 2. Erosion (Z2) showed that the gastrocnemius origin had the second highest frequency of all, particularly in the left lower limb (22.5%). The right *triceps surae* was the only enthesis evidencing presence of all eight types of changes scored with the new Coimbra method. Of these, the frequencies of bone formation (Z1), and (Z2), fine porosity and macro-porosity were the highest values within all the entheses.

As seen in the UdeA collection, score "2" was rarely recorded in any of the entheses. When recorded, bone formation in zone 1 was the feature showing the most score 2 cases overall (mean 2.8%, SD 2.7; median 2%), mainly in the right *triceps surae* enthesis where it reached 9% in the right side, and 6% in the left side. Only two individuals were recorded showing EC scored as "2" in two features, namely erosions (Z1) and bone formation (Z2). The same was true for eight and six individuals showing erosion in zone 2 and fine porosity, respectively. No scores “2” were recorded for either macro-porosity or cavitation.

Pooled frequencies of score 1 and score 2 showed the same trends as those observed in the frequencies of score “1” (Table 3-28), in which bone formation in zone 1, in both the left and the right side, was the most common feature. Both sides of the *triceps surae* insertion (left 83%, right 79%) showed the highest frequencies of bone formation (Z1) of all entheses, while the gastrocnemius origin indicated the lowest frequencies of bone formation (Z1) within all the entheses in the lower limb (left 7.4%, right 9.4%). Frequencies of textural change in the *vastus lateralis* origin were the highest of all entheses (left 59%, right 60%), while the *triceps surae* (left 11%, right 9.5%) had the lowest frequencies of all entheses. The presence of fine porosity was mainly in the *triceps surae* insertion (left 18%, right 17%), while it was rarely recorded in the left *quadriceps femoris* (1%) and was not present in the right *vastus lateralis*. The *triceps surae* insertion evidenced the highest frequencies of erosion (Z1), bone formation (Z2), and macro-porosity among all the entheses.

Presence of EC in the entheses of the lower limbs within each of the three age groups showed that bone formation in zone 1 was the most common within the oldest individuals of the NILMFS collection (Appendix 11). The Chi-square result evidenced that the frequencies of bone formation in all the seven entheses analyzed were different within the age groups either unilaterally or bilaterally (Table 3-29). The *quadriceps femoris*, the patellar ligament, the *triceps surae* and the plantar fascia showed significant differences with effect size ranging from small to medium. While the remaining entheses, the gastrocnemius origin, the iliopsoas, and the *vastus lateralis*, indicated that only one side was statistically significant with medium effect size. The left patellar ligament showed the stronger difference between frequencies of bone formation (Z1) within age groups, followed by the right and the left *quadriceps femoris* entheses. Erosion in zone 1 and zone 2 indicated that only four entheses had differences on only one side. Cramer’s V values ranged from 0.1 to 0.4. These entheses were the left patellar ligament and the right iliopsoas for erosion (Z1), and the right patellar ligament and the right *quadriceps femoris* for erosion (Z2). Textural change evidenced two entheses with significant and bilateral differences in the lower limbs, the insertions of the patellar ligament and the iliopsoas. The former enthesis had medium effect size on both sides, and the latter enthesis was asymmetrical in the strength of the difference, having strong association in the left side (0.4), but not in the right side (0.28). Bone formation in zone 2 showed two entheses, the insertions of the *triceps surae* and the iliopsoas, with differences in both the left and right sides. These had Cramer's V values ≤0.5. The results of the Chi squared test for the left patellar ligament, the left *quadriceps femoris*, and the right gastrocnemius, were significant in only one side, but all effect size values were small.

Fine porosity was the only feature showing the opposite trend of higher frequencies in the younger individuals rather than the older ones. Two entheses, the left *triceps surae* and the iliopsoas insertion, in both the left and the right side, showed significant differences. However, the Cramer's V values were ≤0.3. Macro-porosity and cavitation were mostly absent in the entheses of the lower limbs. Therefore, the majority of the entheses had zero presence or no significant differences.

Table 3-28. Pooled frequencies of EC presence in the entheses on the lower limbs.

		BF (Z1)			ER (Z1)			TC			BF (Z2)			ER (Z2)			FPO			MPO			CA		
Side	**Enthesis**	**N**	**ƒ**	**%**	**N**	**ƒ**	**%**	**N**	**ƒ**	**%**	**N**	**ƒ**	**%**	**N**	**ƒ**	**%**	**N**	**ƒ**	**%**	**N**	**ƒ**	**%**	**N**	**ƒ**	**%**
Left	Iliopsoas	95	20	21.1	95	4	4.21	95	47	49.5	95	23	24.2	95	30	31.6	95	3	3.2	95	3	3.2	95	0	0.0
	Gastrocnemius	94	7	7.45	94	4	4.26	93	24	25.8	93	7	7.53	93	25	26.9	93	5	5.4	93	0	0.0	93	1	1.1
	Quadriceps femoris	89	43	48.3	89	2	2.25	89	17	19.1	89	25	28.1	89	9	10.1	89	1	1.1	89	0	0.0	89	0	0.0
	Vastus Lateralis	85	41	48.2	85	1	1.18	83	49	59	83	10	12	83	2	2.4	83	2	2.4	83	0	0.0	83	0	0.0
	Patella tendon	94	55	58.5	94	11	11.7	89	27	30.3	89	17	19.1	89	5	5.6	89	9	10.1	89	3	3.4	89	0	0.0
	Triceps surae	93	77	82.8	93	7	7.53	91	10	11	91	27	29.7	91	5	5.5	91	16	17.6	91	5	5.5	91	0	0.0
	Plantar Fascia	98	37	37.8	98	1	1.02																		
Right	Iliopsoas	92	19	20.7	92	3	3.26	91	40	44	91	23	25.3	91	22	24.2	91	7	7.7	91	1	1.1	91	0	0.0
	Gastrocnemius	96	9	9.38	96	3	3.13	96	13	13.5	96	13	13.5	96	12	12.5	96	3	3.1	96	1	1.0	96	0	0.0
	Quadriceps femoris	84	40	47.6	84	4	4.76	83	21	25.3	83	23	27.7	83	4	4.8	83	2	2.4	83	1	1.2	83	0	0.0
	Vastus Lateralis	80	42	52.5	80	1	1.25	80	48	60	80	12	15	80	6	7.5	80	0	0.0	80	0	0.0	80	0	0.0
	Patella tendon	96	52	54.2	96	10	10.4	93	22	23.7	93	17	18.3	93	8	8.6	93	7	7.5	93	0	0.0	93	0	0.0
	Triceps surae	97	77	79.4	97	9	9.28	95	9	9.47	95	33	34.7	95	10	10.5	95	16	16.8	95	7	7.4	95	1	1.1
	Plantar Fascia	96	37	38.5	96	2	2.08																		

BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.

Table 3-29. Chi squared test of EC presence by entheses and age groups. Lower limbs of the NILMFS collection.

		BF (Z1)					ER (Z1)					TC					BF (Z2)					ER (Z2)					FPO					MPO					CA				
Side	**Enthesis**	**N**	**X^2**	**df**	**p**	**V**	**N**	**X^2**	**df**	**p**	**V**	**N**	**X^2**	**df**	**p**	**V**	**N**	**X^2**	**df**	**p**	**V**	**N**	**X^2**	**df**	**p**	**V**	**N**	**X^2**	**df**	**p**	**V**	**N**	**X^2**	**df**	**p**	**V**	**N**	**X^2**	**df**	**p**	**V**
Left	Gastrocnemius	94	1.95	2	0.377	0.14	94	2.28	2	0.321	0.16	93	1.70	2	0.428	0.14	93	2.04	2	0.36	0.15	93	0.09	2	0.956	0.03	93	2.05	2	0.36	0.15	93	NaN			NaN	93	1.93	2	0.382	0.14
	Iliopsoas	95	3.48	2	0.176	0.19	95	3.80	2	0.15	0.20	95	15.14	2	**< .001**	**0.40**	95	19.60	2	**< .001**	**0.45**	95	2.24	2	0.326	0.15	95	6.10	2	**0.047**	**0.25**	95	2.14	2	0.342	0.15	95	NaN			NaN
	Patella ligament	94	17.20	2	**< .001**	**0.43**	94	9.18	2	**0.01**	**0.31**	89	8.39	2	**0.015**	**0.31**	89	6.31	2	**0.043**	**0.27**	89	2.65	2	0.266	0.17	89	2.50	2	0.287	0.17	89	2.17	2	0.338	0.16	89	NaN			NaN
	Plantar fascia	98	7.70	2	**0.021**	**0.28**	98	1.90	2	0.386	0.14	0	NaN			NaN	0	NaN			NaN	0	NaN			NaN	0	NaN			NaN	0	NaN			NaN	0	NaN			NaN
	Quadriceps femoris	89	9.20	2	**0.01**	**0.32**	89	1.20	2	0.549	0.12	89	2.75	2	0.253	0.18	89	5.59	2	**0.061**	**0.25**	89	1.72	2	0.424	0.14	89	1.80	2	0.406	0.14	89	NaN			NaN	89	NaN			NaN
	Triceps surae	93	7.94	2	**0.019**	**0.29**	93	0.31	2	0.855	0.06	91	1.50	2	0.472	0.13	91	9.06	2	**0.011**	**0.32**	91	1.59	2	0.453	0.13	91	7.36	2	**0.025**	**0.28**	91	1.59	2	0.453	0.13	91	NaN			NaN
	Vastus lateralis	85	7.67	2	**0.022**	**0.30**	85	1.95	2	0.376	0.15	83	0.69	2	0.708	0.09	83	0.25	2	0.882	0.06	83	3.62	2	0.164	0.21	83	4.03	2	0.134	0.22	83	NaN			NaN	83	NaN			NaN
	Total	648	34.48	2	**< .001**	**0.23**	648	3.92	2	0.141	0.08	540	3.29	2	0.193	0.08	540	23.08	2	**< .001**	**0.21**	540	1.10	2	0.577	0.05	540	7.34	2	**0.026**	**0.12**	540	0.66	2	0.718	0.04	540	1.94	2	0.379	0.06
Right	Gastrocnemius	96	9.61	2	**0.008**	**0.32**	96	2.10	2	0.35	0.15	96	2.15	2	0.342	0.15	96	5.48	2	**0.065**	**0.24**	96	2.40	2	0.301	0.16	96	1.97	2	0.373	0.14	96	2.02	2	0.364	0.15	96	NaN			NaN
	Iliopsoas	92	7.72	2	**0.021**	**0.29**	92	6.74	2	**0.034**	**0.27**	91	6.92	2	**0.031**	**0.28**	91	12.69	2	**0.002**	**0.37**	91	2.82	2	0.244	0.18	91	4.71	2	**0.095**	**0.23**	91	2.16	2	0.339	0.15	91	NaN			NaN
	Patella ligament	96	7.81	2	**0.02**	**0.29**	96	1.85	2	0.396	0.14	93	8.83	2	**0.012**	**0.31**	93	3.15	2	0.207	0.18	93	6.84	2	**0.033**	**0.27**	93	2.56	2	0.278	0.17	93	NaN			NaN	93	NaN			NaN
	Plantar fascia	96	11.09	2	**0.004**	**0.34**	96	4.09	2	0.13	0.21	0	NaN			NaN	0	NaN			NaN	0	NaN			NaN	0	NaN			NaN	0	NaN			NaN	0	NaN			NaN
	Quadriceps femoris	84	14.93	2	**< .001**	**0.42**	84	2.34	2	0.31	0.17	83	1.22	2	0.543	0.12	83	3.80	2	0.149	0.21	83	7.83	2	**0.02**	**0.31**	83	0.94	2	0.626	0.11	83	1.89	2	0.39	0.15	83	NaN			NaN
	Triceps surae	97	6.11	2	**0.047**	**0.25**	97	0.46	2	0.796	0.07	95	0.96	2	0.618	0.10	95	18.30	2	**< .001**	**0.44**	95	0.02	2	0.989	0.02	95	4.12	2	0.128	0.21	95	4.57	2	0.102	0.22	95	2.19	2	0.335	0.15
	Vastus lateralis	80	3.91	2	0.142	0.22	80	1.99	2	0.37	0.16	80	2.20	2	0.332	0.17	80	0.36	2	0.837	0.07	80	0.99	2	0.611	0.11	80	NaN			NaN	80	NaN			NaN	80	NaN			NaN
	Total	641	37.36	2	**< .001**	**0.24**	641	1.14	2	0.565	0.04	538	6.02	2	**0.049**	**0.11**	538	29.38	2	**< .001**	**0.23**	538	11.64	2	**0.003**	**0.15**	538	6.00	2	**0.05**	**0.11**	538	1.15	2	0.564	0.05	538	2.13	2	0.344	0.06

BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.

3.2.2.2. *Comparison between the two skeletal collections*

3.2.2.2.1. General trends of entheseal changes

The proportions of EC present in the entheses were compared between the collections. Four entheses had higher frequency in the NILMFS than the UdeA skeletal collection, but these differences were not significant (Table 3-30). These entheses were both, the left and the right side of the iliopsoas, the patellar ligament, the *triceps surae*, and the left side of the plantar fascia. The opposite trend was observed in both sides of the gastrocnemius, the *quadriceps femoris*, the *vastus lateralis*, and the right plantar fascia, in which the UdeA skeletal collection had the most presence of EC. The Chi squared test evidenced that only the presence of EC in the left *quadriceps femoris* showed a significant difference between the two skeletal collections. However, all Cramer's V values were ≤0.3.

The general differences between the two skeletal collections were further analyzed by feature (Table 3-31). Most of the features showing differences (66%) were more frequent in the NILMFS skeletal collection. All Cramer's V values were <0.3.

The frequencies of the features recorded in the entheses of the lower limbs were pooled into three joint complexes: the hip, the knee, and the ankle/foot. The proportions of EC present in these joint complexes were compared between the two skeletal collections (Table 3-32). The NILMFS skeletal collection evidenced the highest proportions of EC in most of the features within both sides of the three joint complexes. However, the Chi squared test showed that these differences were significant only in the following cases: erosion (Z1) in the right hip, textural change on the right and the left hip, erosion (Z1) of the left and the right ankle/foot, fine porosity in the left ankle, and macro-porosity in the right ankle. However, all Cramer's V values were <0.3.

The Chi squared test showed that erosion (Z2) in the left knee, and textural change in the left and the right ankle/foot joints were significantly more frequent in the UdeA skeletal collection than the NILMFS skeletal collection. but all these differences had small effect size.

Table 3-30. Chi-squared test comparing the pooled frequencies of EC in the lower limbs of individuals from the two skeletal collections.

		NILMFS		UdeA			Pearson Chi-square			
Enthesis	**Side**	**F**	**%**	**f**	**%**	**N**	**Value**	**df**	***p*-value**	**V**
Iliopsoas	Left	77	75.5	47	68.1	171	1.12	1	0.289	0.08
	Right	67	65.7	39	56.5	171	1.47	1	0.226	0.09
Gastrocnemius	Left	59	57.8	40	58.0	171	0.00	1	0.987	0.00
	Right	39	38.2	35	50.7	171	2.62	1	0.106	0.12
Quadriceps femoris	Left	47	46.1	44	63.8	171	5.17	1	**0.023**	**0.17**
	Right	62	60.8	49	71.0	171	1.89	1	0.169	0.11
Vastus lateralis	Left	68	66.7	50	72.5	171	0.65	1	0.421	0.06
	Right	70	68.6	52	75.4	171	0.91	1	0.339	0.07
Patellar ligament	Left	70	68.6	43	62.3	171	0.73	1	0.393	0.07
	Right	66	64.7	41	59.4	171	0.49	1	0.483	0.05
Triceps surae	Left	85	83.3	53	76.8	171	1.12	1	0.289	0.08
	Right	89	87.3	53	76.8	171	3.19	1	0.074	0.14
Plantar fascia	Left	37	36.3	25	36.2	171	0.00	1	0.995	0.00
	Right	37	36.3	32	46.4	171	1.75	1	0.186	0.10

Bold numbers indicate significance at 0.05 level.

Table 3-31. Frequency, Chi squared test, and effect size comparing EC trends of the two skeletal collections by feature. This table presents only significant differences.

			NILMFS			UdeA			Pearson X^2				
Enthesis	**Side**	**Feature**	**N**	**f**	**%**	**N**	**f**	**%**	**Value**	**df**	***p*-value**	**Fisher's (2-sided)**	**V / phi**
Iliopsoas	Left	TC	95	47	49%	61	17	28%	7.17	1	0.007		0.21
	Right	TC	91	40	44%	62	16	26%	5.24	1	0.022		0.19
Gastrocnemius	Right	TC	96	13	14%	67	21	31%	7.58	1	0.006		0.22
Quadriceps femoris	Left	ER(Z1)	89	2	2%	60	10	17%				0.004	0.26
	Right	ER(Z2)	83	4	5%	59	11	19%	6.98	1	0.008		0.22
Patella ligament	Left	ER(Z1)	94	11	12%	58	0	0%				0.007	0.22
Triceps surae	Left	ER(Z1)	93	7	8%	61	0	0%				0.042	0.18
		TC	91	10	11%	64	19	30%	8.64	1	0.003		0.24
		FPO	91	16	18%	64	2	3%	7.65	1	0.006		0.22
	Right	ER(Z2)	95	10	11%	60	1	2%				0.050	0.17
		FPO	95	16	17%	60	3	5%	4.80	1	0.029		0.18
		MPO	95	7	7%	60	0	0%				0.044	0.17

ER(Z1) = erosion zone 1, TC= textural change, ER(Z2)= erosion zone 2, FPO= fine porosity, MPO= macro-porosity.

Table 3-32. Chi squared test and Cramer's V comparing EC presence between the two skeletal collection by joint complexes in the lower limbs.

			NILMFS			UdeA				Pearson Chi-square			Likelihood ratio			
Joint	**Side**	**Feature**	**n**	**f**	**%**	**n**	**f**	**%**	**N**	**Value**	**df**	***p*-value**	**Value**	**df**	***p*-value**	**V**
Hip	Left	BF(Z1)	95	20	21.1	59	9	15.3	154	0.80	1	0.371				0.07
		ER(Z1)	95	4	4.2	59	0	0.0	154				3.93	1	**0.047**	0.13
		TC	95	47	49.5	61	17	27.9	156	7.33	1	**0.007**				**0.21**
		BF(Z2)	95	23	24.2	61	12	19.7	156	0.44	1	0.507				0.05
		ER(Z2)	95	30	31.6	61	25	41.0	156	1.44	1	0.23				0.10
		FPO	95	3	3.2	61	3	4.9	156				0.30	1	0.581	0.05
		MPO	95	3	3.2	61	2.0	3.3	156				0.00	1	0.967	0.00
	Right	BF(Z1)	92	19	20.7	62	8	12.9	154	1.54	1	0.215				0.10
		ER(Z1)	92	3	3.3	62	1	1.6	154				0.42	1	0.516	0.05
		TC	91	40	44.0	62	16	25.8	153	5.24	1	**0.022**				**0.19**
		BF(Z2)	91	23	25.3	62	9	14.5	153	2.58	1	0.108				0.13
		ER(Z2)	91	22	24.2	62	18	29.0	153				0.45	1	0.502	0.05
		FPO	91	7	7.7	62	3	4.8	153				0.51	1	0.476	0.06
		MPO	91	1	1.1	62	2	3.2	153				0.85	1	0.356	0.08
Knee	Left	BF(Z1)	102	76	74.5	69	51	73.9	171	0.01	1	0.93				0.01
		ER(Z1)	102	13	12.7	69	12	17.4	171	0.71	1	0.399				0.07
		TC	102	64	62.7	69	42	60.9	171	0.06	1	0.804				0.02
		BF(Z2)	102	44	43.1	69	30	43.5	171	0.00	1	0.965				0.01
		ER(Z2)	102	15	14.7	69	19	27.5	171	4.25	1	**0.039**				**0.16**
		FPO	102	11	10.8	69	5	7.2	171	0.61	1	0.436				0.06
		MPO	102	3	2.9	69	2	2.9	171				0.00	1	0.987	0.00
	Right	BF(Z1)	102	71	69.6	69	47	68.1	171	0.04	1	0.836				0.02
		ER(Z1)	102	15	14.7	69	7	10.1	171	0.76	1	0.382				0.07
		TC	102	64	62.7	69	42	60.9	171	0.06	1	0.804				0.02
		BF(Z2)	102	40	39.2	69	23	33.3	171	0.61	1	0.434				0.06
		ER(Z2)	102	17	16.7	69	17	24.6	171	1.64	1	0.2				0.10
		FPO	102	9	8.8	69	3	4.3	171				1.34	1	0.247	0.09
		MPO	102	1	1.0	69	0	0.0	171				1.04	1	0.308	0.06
Ankle/foot	Left	BF(Z1)	102	82	80.4	69	52	75.4	171	0.61	1	0.433				0.06
		ER(Z1)	102	10	9.8	69	0	0.0	171				10.75	1	**0.001**	**0.21**
		TC	102	29	28.4	69	37	53.6	171	11.02	1	**0.001**				**0.25**
		BF(Z2)	102	30	29.4	69	30	43.5	171	3.58	1	0.059				0.15
		ER(Z2)	102	30	29.4	69	16	23.2	171	0.81	1	0.368				0.07
		FPO	102	21	20.6	69	2	2.9	171	11.06	1	**0.001**				**0.25**
		MPO	102	5	4.9	69	3	4.3	171				0.03	1	0.866	0.01
		CA	102	1	1.0	69	0	0.0	171				1.04	1	0.308	0.06
	Right	BF(Z1)	102	81	79.4	69	56	81.2	171	0.08	1	0.779				0.02
		ER(Z1)	102	12	11.8	69	2	2.9	171	4.30	1	**0.038**				**0.16**
		TC	102	21	20.6	69	28	40.6	171	8.05	1	**0.005**				**0.22**
		BF(Z2)	102	42	41.2	69	28	40.6	171	0.01	1	0.938				0.01
		ER(Z2)	102	22	21.6	69	7	10.1	171	3.81	1	0.051				0.15
		FPO	102	18	17.6	69	6	8.7	171	2.73	1	0.098				0.13
		MPO	102	8	7.8	69	1	1.4	171				3.98	1	**0.046**	**0.14**
		CA	102	1	1.0	69	0	0.0	171				1.04	1	0.308	0.06

Bold numbers indicate significant ($p<0.05$) differences between the two skeletal collections. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.

3.2.2.2.2. Age range

General differences between the two collections showed that the NILMFS had more frequencies of EC than the UdeA, however trends changed when age was taken into consideration (Table 3-33). The UdeA skeletal collection had higher proportions of EC presence (67%) than the NILMFS skeletal collection (33%). The Chi squared test showed that this trend was significant for the entheses of the right *quadriceps femoris* and the right *vastus lateralis* of the young adult category. The same was true for the entheses of the right gastrocnemius, the left *quadriceps femoris*, and the left *vastus lateralis* of the middle adults and the left iliopsoas of the old adults. Only the difference observed in the left iliopsoas insertion had a Cramer's V value >0.3.

The opposite trend, NILMFS skeletal collection showing higher frequencies of EC presence than the UdeA skeletal collection were significant for the right *triceps surae* of the young adults and the left *triceps surae* of the old adults. Only the differences observed in the right *quadriceps femoris* of the young adult category remained significant after the Bonferroni correction and had medium effect size. The analysis by feature show that differences between the two collections were stronger for textural change and erosion (Table 3-34).

The GLM models with interactions showed that age was a significant factor for EC presence in the patellar ligament and the plantar fascia on the left side (Table 3-35). On the right side, the iliopsoas, the gastrocnemius, the patellar ligament, and the plantar fascia entheses showed the same trend. The collection affected the presence of EC in the left *quadriceps femoris*, the right gastrocnemius, and the right plantar fascia. After the Bonferroni correction, age continued to affect all the entheses, except for the left plantar fascia and the right gastrocnemius. While the collection remained significant only for the left *quadriceps femoris*.

The GLM model without interactions showed that age was a significant factor for the presence of EC in the iliopsoas, patellar ligament, *triceps surae* and the plantar fascia entheses on the left side. On the right side, the same trend was significant for all entheses, except for the *vastus lateralis*. Of these, the left iliopsoas and the right *quadriceps femoris* entheses were no longer affected by age after the Bonferroni correction. The collection affected the presence of EC in the left *quadriceps femoris*, the right gastrocnemius, and the right plantar fascia entheses, however none of these entheses continued to be affected by collection after the Bonferroni correction.

Table 3-33. Chi squared test and Cramer's V comparing the presence of EC between the two skeletal collections in the entheses in the lower limbs by side.

						Pearson X^2			**Likelihood ratio X^2**			
Enthesis	**Side**	**Age range**	**N**	**f**	**%**	**Value**	**df**	***p*-value**	**Value**	**df**	***p*-value**	**V**
Iliopsoas	Left	Young adult	71	45	63%	0.16	1	0.687				0.05
		Middle adult	53	39	74%	0.00	1	0.99				0.00
		Old adult	47	40	85%				5.50	1	**0.019**	0.36
	Right	Young adult	71	34	48%	0.13	1	0.718				0.04
		Middle adult	53	31	58%	0.00	1	0.948				0.01
		Old adult	47	41	87%				0.98	1	0.323	0.15
Gastrocnemius	Left	Young adult	71	40	56%	0.02	1	0.893				0.02
		Middle adult	53	27	51%	0.15	1	0.697				0.05
		Old adult	47	32	68%				0.28	1	0.594	0.08
	Right	Young adult	71	25	35%	0.69	1	0.405				0.10
		Middle adult	53	21	40%	4.13	1	**0.042**				0.28
		Old adult	47	28	60%	0.46	1	0.498				0.10
Quadriceps femoris	Left	Young adult	71	19	27%	0.13	1	0.718				0.04
		Middle adult	53	14	26%	4.30	1	**0.038**				0.29
		Old adult	47	11	23%	3.59	1	0.058				0.28
	Right	Young adult	71	40	56%	6.39	1	**0.011***				0.30
		Middle adult	53	35	66%	0.08	1	0.784				0.04
		Old adult	47	36	77%				0.13	1	0.72	0.05
Vastus lateralis	Left	Young adult	71	24	34%	0.17	1	0.677				0.05
		Middle adult	53	16	30%	4.36	1	**0.037**				0.29
		Old adult	47	10	21%				1.21	1	0.28	0.16
	Right	Young adult	71	29	41%	4.15	1	**0.042**				0.24
		Middle adult	53	14	26%	0.21	1	0.646				0.06
		Old adult	47	9	19%				1.62	1	0.203	0.19
	Left	Young adult	71	17	24%	0.01	1	0.909				0.01
Patella ligament		Middle adult	53	13	25%				0.78	1	0.378	0.12
		Old adult	47	13	28%				0.22	1	0.639	0.07
	Right	Young adult	71	16	23%	0.01	1	0.914				0.01
		Middle adult	53	14	26%	0.06	1	0.81				0.03
		Old adult	47	11	23%				0.37	1	0.542	0.09
Triceps surae	Left	Young adult	71	22	31%	1.22	1	0.269				0.13
		Middle adult	53	16	30%				0.57	0	0.451	0.11
		Old adult	47	15	32%				4.12	1	**0.042**	0.24
	Right	Young adult	71	21	30%	4.78	1	**0.029**				0.26
		Middle adult	53	17	32%				0.02	1	0.891	0.02
		Old adult	47	15	32%				2.40	1	0.121	0.18
Plantar fascia	Left	Young adult	71	10	14%	0.81	1	0.368				0.11
		Middle adult	53	10	19%	1.03	1	0.311				0.14
		Old adult	47	5	11%	1.61	1	0.205				0.19
	Right	Young adult	71	10	14%	1.44	1	0.23				0.14
		Middle adult	53	11	21%	0.93	1	0.336				0.13
		Old adult	47	11	23%	2.28	1	0.132				0.22

*Bold numbers indicate significance at 0.05 level. * Indicates significance at 0.05 level after the Bonferroni correction.*

Table 3-34. Frequency, Fisher's exact test, and effect size comparing EC trends between the two skeletal collections by feature.

				NILMFS			**UdeA**			**Fisher's**	
Enthesis	**Side**	**Feature**	**Age range**	**N**	**f**	**%**	**N**	**f**	**%**	**(2-sided)**	**Phi**
Iliopsoas	Left	TC	Old adult	31	21	68%	13	3	23%	0.009	**-0.41**
		ER(Z2)	Middle adult	32	7	22%	15	8	53%	0.046	**0.32**
	Right	BF(Z1)	Young adult	32	4	13%	33	0	0%	0.053	-0.26
		TC	Old adult	29	17	59%	15	2	13%	0.005	**-0.43**
Gastrocnemius	Right	TC	Middle adult	31	2	6%	18	9	50%	0.001	**0.50**
Quadriceps femoris	Right	ER(Z2)	Young adult	28	0	0%	32	7	22%	0.012	**0.34**
Vastus lateralis	Right	TC	Middle adult	25	18	72%	15	6	40%	0.094	**-0.32**
Patella ligament	Left	ER(Z1)	Old adult	31	8	26%	14	0	0%	0.044	**-0.31**
Triceps surae	Left	BF(Z2)	Middle adult	31	12	39%	16	11	69%	0.069	0.29
		FPO	Middle adult	31	10	32%	16	1	6%	0.070	-0.29
		TC	Middle adult	31	2	6%	16	5	31%	0.036	**0.33**
		TC	Old adult	29	3	10%	15	6	40%	0.044	**0.35**
	Right	BF(Z2)	Young adult	36	3	8%	30	8	27%	0.094	0.25
		FPO	Young adult	36	6	17%	30	0	0%	0.028	-0.29
		MPO	Young adult	36	5	14%	30	0	0%	0.058	-0.26

Bold numbers indicate medium effect size. BF(Z1)= bone formation zone 1, ER(Z1)= erosion zone 1, TC= textural change, BF(Z2)= bone formation zone 2, ER(Z2)=erosion zone 2, FPO= fine porosity, MPO= macro-porosity.

Table 3-35. GLM models for the entheses in the lower limbs considering age and collection as predictors.

	Side	Parameter	Iliopsoas	Gastrocnemius	Quadriceps femoris	Vastus lateralis	Patella ligament	Triceps surae	Plantar fascia
NILMFS	Left	N	102	102	102	102	102	102	102
		EC presence	77	59	47	68	70	85	37
		%	75%	58%	46%	67%	69%	83%	36%
UdeA		N	69	69	69	69	69	69	69
		EC presence	47	40	44	50	43	53	25
		%	68%	58%	64%	72%	62%	77%	36%
GLM model with		AICC	32.987	34.239	34.610	33.691	33.362	-	34.294
interactions		(Intercept)	0.000	0.030	0.092	0.000	0.000	-	0.001
		Collection	0.133	0.839	**0.008***	0.435	0.922	-	0.794
		Age	0.056	0.166	0.655	0.609	**<0.001***	-	**0.025**
		Collection*Age	0.075	0.803	0.252	0.078	0.614	-	0.196
		AICC	33.905	30.918	33.097	34.523	30.065	30.581	33.286
GLM model without		(Intercept)	0.000	0.029	0.171	0.000	0.000	0.000	0.002
interactions		Collection	0.490	0.900	**0.019**	0.336	0.848	0.566	0.648
		Age	**0.040**	0.203	0.827	0.354	**<0.001***	**0.007***	**0.014***
	Right	N	102	102	102	102	102	102	102
		EC presence	67	39	62	70	66	89	37
		%	66%	38%	61%	69%	65%	87%	36%
		N	69	69	69	69	69	69	69
		EC presence	39	35	49	52	41	53	32
		%	57%	51%	71%	75%	59%	77%	46%
GLM model with		AICC	33.600	34.589	33.552	33.739	33.963	-	34.080
interactions		(Intercept)	0.000	0.411	0.000	0.000	0.000	-	0.183
		Collection	0.348	**0.041**	0.276	0.614	0.819	-	**0.031**
		Age	**<0.001***	**0.026**	0.137	0.914	**<0.001***	-	**<0.001***
		Collection*Age	0.718	0.560	0.168	0.076	0.804	-	0.874
		AICC	29.991	31.477	33.360	34.616	30.128	29.853	30.078
GLM model without		(Intercept)	0.000	0.375	0.000	0.000	0.000	0.000	0.137
interactions		Collection	0.503	**0.042**	0.076	0.335	0.944	0.195	**0.035**
		Age	**<0.001***	**0.013***	**0.039**	0.953	**<0.001***	**0.007***	**<0.001***

*Bold numbers indicate significance at 0.05 level. * Indicates significance at 0.05 level after the Bonferroni correction.*

3.2.2.2.2.1. Joint complexes in the lower limbs

The presence of EC in the joint complexes of the three age ranges was compared between the two skeletal collections. The Chi squared test, and GLM models were used to test whether the joint complexes of individuals from the two collections had different EC trends when age was controlled for.

3.2.2.2.2.1.1. Hip

The iliopsoas insertion is the only enthesis in the hip joint complex. When this joint was compared between the two collections, the NILMFS (54.7%) evidenced higher EC presence than the UdeA skeletal collection (35.7%) in more than half of the features. The Chi squared tests showed that the young adults from the NILMFS collection had more presence of bone formation (Z1) than the UdeA collection, where four cases were recorded in the NILMFS skeletal collection and none was found in the UdeA skeletal collection. the Cramer’s V value

<0.3 (Table 3-36). The opposite trend was observed in the presence of erosion (Z2), in which the middle adults from the UdeA collection had higher frequencies in the left hip. Even though this result was not statistically significant after the Bonferroni correction, the difference showed a medium effect size. The old adults showed differences in the presence of textural change in both the left and the right side. The NILMFS collection had higher proportions than the UdeA collection on both sides, with Cramer's V values ≤0.5.

The results of the GLM models with and without interactions showed that age was a significant factor for the presence of textural change and bone formation (Z2) in the left hip, while the collection only affected the presence of textural change (Table 3-37). Yet, the effect of the collection ceased after the Bonferroni correction. On the right side, both GLM models evidenced that all the features, except for macro-porosity were impacted by age. In the GLM model with interactions, textural change and fine porosity were no longer affected by age after the Bonferroni correction. The same was true for textural change in the GLM model without interactions. The collection affected the presence of textural change in the model with interactions, but not in the GLM model without interactions. However, the collection had no effect on textural change after the Bonferroni correction.

Table 3-36. Chi squared test and Cramer's V comparing presence of EC in the hip between the two skeletal collections by age ranges.

						Pearson X^2			**Likelihood ratio X^2**			
Feature	**Side**	**Age range**	**N**	**f**	**%**	**Value**	**df**	***p*-value**	**Value**	**df**	***p*-value**	**V**
BF(Z1)	Left	Young adult	63	7	11%				1.38	1	0.239	0.15
		Middle adult	47	9	19%				0.77	1	0.38	0.13
		Old adult	44	13	30%				0.38	1	0.537	0.09
	Right	Young adult	65	4	6%				5.94	1	**0.015***	**0.26**
		Middle adult	45	8	18%				1.53	1	0.216	0.19
		Old adult	44	15	34%	0.56	1	0.455				0.11
ER(Z1)	Left	Young adult	63	1	2%				2.19	1	0.14	0.13
		Middle adult	47	0	0%							
		Old adult	44	3	7%				2.19	1	0.139	0.18
	Right	Young adult	65	0	0%							
		Middle adult	45	1	2%				2.39	1	0.122	0.22
		Old adult	44	3	7%				2.61	1	0.106	0.20
TC	Left	Young adult	65	15	23%	0.05	1	0.821				0.03
		Middle adult	47	25	53%	1.54	1	0.215				0.18
		Old adult	44	24	55%	7.37	1	**0.007***				**0.41**
	Right	Young adult	64	15	23%	0.19	1	0.665				0.05
		Middle adult	45	22	49%	0.10	1	0.92				0.02
		Old adult	44	19	43%	8.26	1	**0.004***				**0.43**
BF(Z2)	Left	Young adult	65	6	9%				0.68	1	0.409	0.10
		Middle adult	47	9	19%				0.77	1	0.38	0.13
		Old adult	44	20	45%	1.61	1	0.205				0.19
	Right	Young adult	64	5	8%				0.29	1	0.589	0.07
		Middle adult	45	8	18%				0.18	1	0.676	0.06
		Old adult	44	19	43%	0.90	1	0.343				0.14
ER(Z2)	Left	Young adult	65	21	32%	0.12	1	0.726				0.04
		Middle adult	47	15	32%				4.52	1	**0.034**	**0.32**
		Old adult	44	19	43%	0.86	1	0.355				0.14
	Right	Young adult	64	10	16%				0.01	1	0.914	0.01
		Middle adult	45	13	29%				1.87	1	0.172	0.21
		Old adult	44	17	39%	0.61	1	0.433				0.12
FPO	Left	Young adult	65	6	9%				0.00	1	0.968	0.01
		Middle adult	47	0	0%							
		Old adult	44	0	0%							
	Right	Young adult	64	8	13%				0.73	1	0.393	0.11
		Middle adult	45	1	2%				0.76	1	0.385	0.10
		Old adult	44	1	2%				0.85	1	0.358	0.11
MPO	Left	Young adult	65	2	3%				2.77	1	0.096	0.18
		Middle adult	47	1	2%				0.78	1	0.377	0.10
		Old adult	44	2	5%				1.44	1	0.23	0.14
	Right	Young adult	64	1	2%				1.34	1	0.247	0.12
		Middle adult	45	1	2%				2.39	1	0.122	0.22
		Old adult	44	1	2%				0.85	1	0.358	0.11

*Bold numbers indicate significance at 0.05 level. * Indicates significance at 0.05 level after the Bonferroni correction. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity.*

Table 3-37. GLM models with and without interaction comparing presence of EC between the two skeletal collections by feature in the hip.

	Side	Parameter	BF(Z1)	ER(Z1)	TC	BF(Z2)	ER(Z2)	FPO	MPO	CA	Overall
NILMFS	Left	N	95	95	95	95	95	95	95	95	102
		EC presence	20	4	47	23	30	3	3	0	77
		%	21%	4%	49%	24%	32%	3%	3%	0%	75%
UdeA		N	59	59	61	61	61	61	61	61	69
		EC presence	9	0	17	12	25	3	2	0	47
		%	15%	0%	28%	20%	41%	5%	3%	0%	68%
GLM model with interactions		AICC	31.205	17.43	33.343	31.326	33.845	-	-	-	32.987
		(Intercept)	0.000	0.000	0.010	0.000	0.007	-	-	-	0.000
		Collection	0.573	0.993	**0.022**	0.701	0.09	-	-	-	0.133
		Age	0.092	1.000	**0.013***	**0.002***	0.382	-	-	-	0.056
		Collection*Age	0.322	1	0.083	0.213	0.168	-	-	-	0.075
GLM model without interactions		AICC	29.172	-	34.027	30.117	33.112	-	20.32	-	33.905
		(Intercept)	0.000	-	0.025	0.000	0.002	-	0.000	-	0.000
		Collection	0.604	-	**0.04**	0.94	0.165	-	0.943	-	0.490
		Age	0.075	-	**0.002***	**<0.001***	0.340	-	0.806	-	**0.040**
NILMFS	Right	N	92	92	91	91	91	91	91	91	102
		EC presence	19	3	40	23	22	7	1	0	67
		%	21%	3%	44%	25%	24%	8%	1%	0%	66%
UdeA		N	62	62	62	62	62	62	62	62	69
		EC presence	8	1	16	9	18	3	2	0	39
		%	13%	2%	26%	15%	29%	5%	3%	0%	57%
GLM model with interactions		AICC	-	-	33.093	30.838	32.784	22.711	-	-	33.600
		(Intercept)	-	-	0.001	0.000	0.000	0.000	-	-	0.000
		Collection	-	-	**0.04**	0.297	0.239	0.159	-	-	0.348
		Age	-	-	**0.029**	**<0.001***	**0.014***	**0.022**	-	-	**<0.001***
		Collection*Age	-	-	0.052	0.973	0.578	0.66	-	-	0.718
GLM model without interactions		AICC	31.645	-	34.696	26.588	29.575	19.237	17.707	-	29.991
		(Intercept)	0.000	-	0.001	0.000	0.000	0.000	0.000	-	0.000
		Collection	0.441	-	0.067	0.25	0.238	0.221	0.318	-	0.503
		Age	**0.001***	-	**0.034**	**<0.001***	**0.014***	**0.023***	0.887	-	**<0.001***

*Bold numbers indicate significance at 0.05 level. * Indicates significance at 0.05 level after the Bonferroni correction. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.*

3.2.2.2.2.1.2. Knee

The presence of EC in the knees of the individuals from the two skeletal collections were analyzed within each age category (Table 3-38). The NILMFS skeletal collection showed higher frequencies of EC in twenty-one of the features (50%) than the UdeA skeletal collection. However, none of the features showed a significant difference between the two. The opposite trend was observed in nineteen features (45%), of those the Chi-squared tests showed that the differences in the presence of erosion (Z2) in the left knee of the middle adult category and the right knee of the young adult category were significant. Only the difference in the proportions present in the young adults remained significant after the Bonferroni correction and the difference had a Cramer's V value <0.5.

The GLM model with and without interactions evidenced that the presence of bone formation in both zones 1 and 2 on the left and the right knee was affected by age (Table 3-39). The collection affected the presence of erosion (Z2) in the model with interactions on the left knee. The GLM model with the features recorded in the right knee showed that the interaction of collection and age affected the presence of erosion in zone 2. The trends evidenced on both the right and the left knee remained significant after the Bonferroni correction, except for the effect of the collection over erosion (Z2) on the left knee.

Table 3-38. Chi squared test and Cramer's V comparing presence of EC in the knee joint complex between the two skeletal collections by age ranges.

						Pearson X^2			**Likelihood ratio X^2**			
Feature	**Side**	**Age range**	**N**	**f**	**%**	**Value**	**df**	***p*-value**	**Value**	**df**	***p*-value**	**V**
BF(Z1)	Left	Young adult	71	40	56%	1.19	1	0.275				0.13
		Middle adult	53	45	85%				0.01	1	0.916	0.02
		Old adult	47	42	89%				0.16	1	0.687	0.06
	Right	Young adult	71	33	46%	0.12	1	0.727				0.04
		Middle adult	53	45	85%				0.51	1	0.477	0.10
		Old adult	47	40	85%				0.04	1	0.836	0.03
ER(Z1)	Left	Young adult	71	7	10%				1.56	1	0.211	0.15
		Middle adult	53	8	15%				2.79	1	0.095	0.23
		Old adult	47	10	21%				0.89	1	0.347	0.13
	Right	Young adult	71	8	11%				0.51	1	0.476	0.08
		Middle adult	53	7	13%				0.19	1	0.662	0.06
		Old adult	47	7	15%				0.04	1	0.836	0.03
TC	Left	Young adult	71	45	63%	0.80	1	0.371				0.11
		Middle adult	53	29	55%	0.65	1	0.422				0.11
		Old adult	47	32	68%				0.65	1	0.42	0.12
	Right	Young adult	71	44	62%	2.62	1	0.106				0.19
		Middle adult	53	28	53%	1.37	1	0.242				0.16
		Old adult	47	34	72%				1.62	1	0.203	0.19
BF(Z2)	Left	Young adult	71	18	25%	0.23	1	0.634				0.06
		Middle adult	53	25	47%	0.36	1	0.552				0.08
		Old adult	47	31	66%	1.94	1	0.164				0.20
	Right	Young adult	71	14	20%	0.29	1	0.591				0.06
		Middle adult	53	23	43%	0.19	1	0.663				0.06
		Old adult	47	26	55%	0.04	1	0.851				0.03
ER(Z2)	Left	Young adult	71	17	24%	0.81	1	0.368				0.11
		Middle adult	53	7	13%				4.26	1	**0.039**	**0.29**
		Old adult	47	10	21%				0.37	1	0.542	0.09
	Right	Young adult	71	14	20%	9.25	1	**0.002***				**0.36**
		Middle adult	53	6	11%				0.57	1	0.451	0.11
		Old adult	47	14	30%				3.13	1	0.077	0.25
FPO	Left	Young adult	71	8	11%				2.22	1	0.136	0.17
		Middle adult	53	5	9%				0.04	1	0.84	0.03
		Old adult	47	3	6%				0.00	1	0.957	0.01
	Right	Young adult	71	4	6%				1.05	1	0.306	0.12
		Middle adult	53	6	11%				0.02	1	0.891	0.02
		Old adult	47	2	4%				1.58	1	0.209	0.14
MPO	Left	Young adult	71	1	1%				1.43	1	0.232	0.12
		Middle adult	53	1	2%				0.90	1	0.343	0.10
		Old adult	47	3	6%				0.00	1	0.957	0.01
	Right	Young adult	71	0	0%				-	-	-	-
		Middle adult	53	0	0%				-	-	-	-
		Old adult	47	1	2%				0.78	1	0.377	0.10

*Bold numbers indicate significance at 0.05 level. * Indicates significance at 0.05 level after the Bonferroni correction. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity.*

Table 3-39. GLM models with and without interaction comparing presence of EC between the two skeletal collections by feature in the knee joint complex.

	Side	Parameter	BF(Z1)	ER(Z1)	TC	BF(Z2)	ER(Z2)	FPO	MPO	CA	Overall
NILMFS	Left	N	102	102	102	102	102	102	102	102	102
		EC presence	76	13	64	44	15	11	3	0	79
		%	75%	13%	63%	43%	15%	11%	3%	0%	77%
UdeA		N	69	69	69	69	69	69	69	69	69
		EC presence	51	12	42	30	19	5	2	0	53
		%	74%	17%	61%	43%	28%	7%	3%	0%	77%
GLM model with interactions		AICC	32.026	30.599	34.67	34.094	32.07	28.428	-	-	-
		(Intercept)	0.000	0.000	0.007	0.623	0.000	0.000	-	-	-
		Collection	0.973	0.284	0.584	0.311	**0.033**	0.602	-	-	-
		Age	**<0.001***	0.35	0.384	**<0.001***	0.325	0.801	-	-	-
		Collection*Age	0.63	0.137	0.362	0.363	0.43	0.496	-	-	-
GLM model without interactions		AICC	28.68	30.306	32.431	31.851	29.485	25.56	18.961	-	22.597
		(Intercept)	0.000	0.000	0.003	0.378	0.000	0.000	0.000	-	0.000
		Collection	0.505	0.262	0.796	0.44	0.053	0.353	0.855	-	0.622
		Age	**<0.001***	0.175	0.37	**<0.001***	0.373	0.585	0.292	-	0.182
NILMFS	Right	N	102	102	102	102	102	102	102	102	102
		EC presence	71	15	64	40	17	9	1	0	77
		%	70%	15%	63%	39%	17%	9%	1%	0%	75%
UdeA		N	69	69	69	69	69	69	69	69	69
		EC presence	47	7	42	23	17	3	0	0	56
		%	68%	10%	61%	33%	25%	4%	0%	0%	81%
GLM model with interactions		AICC	31.809	30.357	34.456	34.158	31.052	-	-	-	-
		(Intercept)	0.000	0.000	0.007	0.005	0.000	-	-	-	-
		Collection	0.47	0.447	0.471	0.856	0.312	-	-	-	-
		Age	**<0.001***	0.869	0.163	**<0.001***	0.415	-	-	-	-
		Collection*Age	0.903	0.956	0.061	0.782	**0.003***	-	-	-	-
GLM model without interactions		AICC	28.253	26.175	35.783	30.378	38.586	22.689	-	-	29.216
		(Intercept)	0.000	0.000	0.002	0.004	0.000	0.000	-	-	0.000
		Collection	0.495	0.419	0.849	0.878	0.164	0.26	-	-	0.477
		Age	**<0.001***	0.901	0.132	**<0.001***	0.057	0.355	-	-	0.069

*Bold numbers indicate significance at 0.05 level. * Indicates significance at 0.05 level after the Bonferroni correction. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.*

3.2.2.2.2.1.3. Ankle and foot

The differences of EC presence in the ankle and foot joint complex of the individuals from the two skeletal collections were analyzed within each age category and compared between each other (Table 3-40). Twenty-two features (46%) were more frequent in the NILMFS skeletal collection compared to the UdeA skeletal collection. Of those, the Chi squared test showed that only the presence of erosion (Z1) in the left and the right ankle/foot of the young adults, and fine porosity in the left ankle/foot of the middle adults were significantly different between the two collections. The differences observed in erosion (Z1) in the right ankle/foot and fine porosity in the left ankle/foot remained significant after the Bonferroni correction. Only the difference observed in the presence of fine porosity had a Cramer’s V value <0.5.

Twenty-two cases (46%) evidenced the opposite trend, in which the UdeA skeletal collection had higher proportions of EC presence than the NILMFS skeletal collection. Of those, the results of the Chi squared test showed significant differences in the presence of textural change in the left and the right ankle/foot and the presence of bone formation (Z2) in the left knee of the individuals from the middle adult category were significant. The trend observed in textural change of both ankle/foot joints continued to be significant after the Bonferroni correction. The effect size of the three differences in the middle adults were medium. The presence of bone formation (Z1) in the right ankle/foot joint of the individuals from the old adult category was also significantly higher in the UdeA skeletal collection compared to the proportions of the NILMFS skeletal collection. However, this difference was no longer significant after the Bonferroni correction and the difference had a Cramer’s V value <0.3.

In general, the presence of EC in the features of the ankle/foot joint was more affected by the collection than the other joints in the lower limbs. Age continued to be a major factor to be considered (Table 3-41). On the left side, the GLM model with interactions could be calculated for three out of the eight features recorded. Of those, textural change and bone formation (Z2) were affected by the collection, and the presence of bone formation (Z2) was also affected by age. The GLM model without interactions evidenced that the collection affected the presence of textural change, bone formation (Z2), and fine porosity, while age impacted the presence of bone formation in zone 1 and 2, and fine porosity. All the trends remained significant after the Bonferroni correction.

On the right side, the GLM model with interactions showed that the collection had an effect on the presence of textural change and erosion (Z2), age affected the presence of bone formation (Z2), and the interaction of collection and age, impacted the presence of textural change. Both factors, the collection and age, affected the presence of textural change and bone formation (Z2), respectively, after the Bonferroni correction. The GLM model without interactions showed that the presence of erosion (Z1), textural change, and macro-porosity was affected by the collection, while age was a significant factor affecting the presence of bone formation in both zones. All the trends remained significant after the Bonferroni correction, except for the effect of collection in erosion (Z1).

Table 3-40. Chi squared test and Cramer's V comparing presence of EC in the ankle/foot joint complex between the two skeletal collections by age ranges.

						Pearson X^2			**Likelihood ratio X^2**			
Feature	**Side**	**Age range**	**N**	**f**	**%**	**Value**	**df**	***p*-value**	**Value**	**df**	***p*-value**	**V**
BF(Z1)	Left	Young adult	71	46	65%	0.11	1	0.737				0.04
		Middle adult	53	45	85%				0.79	1	0.373	0.12
		Old adult	47	43	91%				3.25	1	0.072	0.21
	Right	Young adult	71	48	68%	0.11	1	0.737				0.04
		Middle adult	53	47	89%				1.21	1	0.272	0.14
		Old adult	47	42	89%				4.12	1	**0.042**	**0.24**
ER(Z1)	Left	Young adult	71	3	4%				4.20	1	**0.04**	**0.21**
		Middle adult	53	3	6%				2.76	1	0.096	0.18
		Old adult	47	4	9%				3.25	1	0.072	0.21
	Right	Young adult	71	4	6%				5.67	1	**0.017***	**0.24**
		Middle adult	53	4	8%				0.23	1	0.629	0.07
		Old adult	47	6	13%				0.81	1	0.367	0.13
TC	Left	Young adult	71	30	42%	2.38	1	0.123				0.18
		Middle adult	53	17	32%	5.74	1	**0.017***				**0.33**
		Old adult	47	19	40%	3.51	1	0.061				0.27
	Right	Young adult	71	18	25%	0.38	1	0.539				0.07
		Middle adult	53	16	30%	15.28	1	**<0.001***				**0.54**
		Old adult	47	15	32%				0.65	1	0.42	0.12
BF(Z2)	Left	Young adult	71	9	13%				1.26	1	0.261	0.13
		Middle adult	53	26	49%	4.44	1	**0.035**				**0.29**
		Old adult	47	25	53%	3.59	1	0.058				0.28
	Right	Young adult	71	14	20%	0.43	1	0.512				0.08
		Middle adult	53	24	45%	0.05	1	0.82				0.03
		Old adult	47	32	68%				0.28	1	0.594	0.80
ER(Z2)	Left	Young adult	71	15	21%	0.66	1	0.417				0.10
		Middle adult	53	14	26%	1.72	1	0.19				0.18
		Old adult	47	17	36%	1.05	1	0.305				0.15
	Right	Young adult	71	8	11%				2.22	1	0.136	0.17
		Middle adult	53	11	21%				0.00	1	0.968	0.01
		Old adult	47	10	21%				3.28	1	0.07	0.24
FPO	Left	Young adult	71	6	8%				3.04	1	0.081	0.20
		Middle adult	53	14	26%	6.82	1	**0.009***				**0.36**
		Old adult	47	3	6%				2.40	1	0.121	0.18
	Right	Young adult	71	11	15%	2.53	1	0.112				0.19
		Middle adult	53	10	19%				1.45	1	0.229	0.16
		Old adult	47	3	6%				0.00	1	0.957	0.01
MPO	Left	Young adult	71	6	8%				0.00	1	0.971	0.00
		Middle adult	53	1	2%				0.90	1	0.343	0.10
		Old adult	47	1	2%				0.78	1	0.377	0.10
	Right	Young adult	71	6	8%				3.04	1	0.081	0.20
		Middle adult	53	2	4%				1.82	1	0.177	0.15
		Old adult	47	1	2%				0.78	1	0.377	0.10
CA	Left	Young adult	71	0	0%				-	-	-	-
		Middle adult	53	0	0%				-	-	-	-
		Old adult	47	1	2%				0.779	1	0.377	0.10
	Right	Young adult	71	0	0%				-	-	-	-
		Middle adult	53	1	2%				0.90	1	0.343	0.10
		Old adult	47	0	0%				-	-	-	-

*Bold numbers indicate significance at 0.05 level. * Indicates significance at 0.05 level after the Bonferroni correction. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.*

Table 3-41. GLM models with and without interaction comparing presence of EC between the two skeletal collections by feature in the ankle/foot joint complex.

	Side	Parameter	BF(Z1)	ER(Z1)	TC	BF(Z2)	ER(Z2)	FPO	MPO	CA	Overall
NILMFS	Left	N	102	102	102	102	102	102	102	102	89
		EC presence	82	10	29	30	30	21	5	1	82
		%	80%	10%	28%	29%	29%	21%	5%	1%	92%
UdeA		N	69	69	69	69	69	69	69	69	61
		EC presence	52	0	37	30	16	2	3	0	53
		%	75%	0%	54%	43%	23%	3%	4%	0%	87%
GLM model with interactions		AICC	-	-	34.403	32.984	33.408	-	-	-	-
		(Intercept)	-	-	0.027	0.014	0.000	-	-	-	-
		Collection	-	-	**0.001***	**0.004***	0.501	-	-	-	-
		Age	-	-	0.604	**<0.001***	0.111	-	-	-	-
		Collection*Age	-	-	0.656	0.887	0.215	-	-	-	-
GLM model without interactions		AICC	29.544	-	30.976	28.953	32.209	22.870	19.440	-	22.733
		(Intercept)	0.000	-	0.018	0.004	0.000	0.000	0.000	-	0.000
		Collection	0.834	-	**0.001***	**0.002***	0.506	**<0.001***	0.635	-	0.529
		Age	**0.001***	-	0.574	**<0.001***	0.243	**0.006***	0.13	-	0.064
NILMFS	Right	N	102	102	102	102	102	102	102	102	61
		EC presence	81	12	21	42	22	18	8	1	54
		%	79%	12%	21%	41%	22%	18%	8%	1%	89%
UdeA		N	69	69	69	69	69	69	69	69	35
		EC presence	56	2	28	28	7	6	1	0	27
		%	81%	3%	41%	41%	10%	9%	1%	0%	77%
GLM model with interactions		AICC	-	-	33.397	33.859	30.811	29.759	-	-	-
		(Intercept)	-	-	0.000	0.166	0.000	0.000	-	-	-
		Collection	-	-	**0.002***	0.409	**0.047**	0.220	-	-	-
		Age	-	-	0.570	**<0.001***	0.274	0.331	-	-	-
		Collection*Age	-	-	**0.026**	0.943	0.313	0.735	-	-	-
GLM model without interactions		AICC	29.341	23.926	36.417	29.705	28.865	26.103	31.951	-	-
		(Intercept)	0.000	0.000	0.000	0.156	0.000	0.000	0.000	-	-
		Collection	0.395	**0.039**	**0.003***	0.42	0.075	0.063	**0.023***	-	-
		Age	**0.002***	0.543	0.416	**<0.001***	0.357	0.11	0.147	-	-

*Bold numbers indicate significance at 0.05 level. * Indicates significance at 0.05 level after the Bonferroni correction. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.*

3.2.2.2.3. Asymmetries

As seen in the asymmetry by each collection, the overall asymmetries of EC presence in the lower limbs varied by enthesis and collection, but none of the overall asymmetries differed significantly between the two skeletal collections (Table 3-42). The individuals from the NILMFS skeletal collection showed higher frequencies of EC on the right iliopsoas compared to the left side, while the UdeA skeletal collection had the opposite trend, in which the left side showed the highest frequencies of EC. The overall frequencies of EC presence of both skeletal collections showed that the gastrocnemius and the patellar ligament entheses had more EC on the right side than the left side, however the proportions of EC presence in the gastrocnemius origin were higher than those observed in the patellar ligament. The *quadriceps femoris*, *vastus lateralis*, *triceps surae* and the plantar fascia entheses showed a higher frequency of EC in the left side compared to the right side. The proportions of EC in the *quadriceps femoris* were higher in the NILMFS skeletal collection than the UdeA skeletal collection. The *vastus lateralis* and the plantar fascia evidenced the opposite, the proportions of EC presence in the NILMFS collection were lower than those observed in the UdeA skeletal collection. The *triceps surae* and the plantar fascia also showed the same proportions of left-side and right-side asymmetry in the NILMFS and the UdeA skeletal collections respectively.

The comparison of bilateral asymmetries by feature evidenced that the majority of entheses and features were not different between the two skeletal collections. The Chi squared test results of the erosion in both zones were the only feature showing differences in three different entheses, the *quadriceps femoris*, the patellar ligament, and the *triceps surae*. The right-side asymmetry of the ER(Z1) was more frequent in the UdeA skeletal collection than the NILMFS skeletal collection for the *quadriceps femoris*. The opposite trend was observed in the ER(Z2) of the patellar ligament, in which the left-side asymmetry of the NILMFS skeletal collection was higher than the left-side asymmetry of the UdeA skeletal collection. The UdeA skeletal collection also showed that the proportions of no-side asymmetry of the ER(Z1) of the *triceps surae* were higher than the NILMFS collection. However, the trends of the three entheses were no longer significant after the Bonferroni correction, and all Cramer's V values were <0.3.

3.2.2.2.3.1. Asymmetry by joint complexes

The bilateral asymmetries of the joint complexes in the lower limbs were compared between the two skeletal collections (Table 3-43). The Chi squared test results evidenced that the UdeA skeletal collection has significantly higher proportions of no-side asymmetry in the erosion in both zones and the fine-porosity features than the NILMFS skeletal collection. The same was true for the right-side asymmetry of the erosion (Z1). Erosion in zone two evidenced that the proportions of left-side asymmetries of the NILMFS skeletal collection were high compared to the proportions of the UdeA skeletal collection. Fine porosity was more frequent in the right side in the NILMFS skeletal collection than the UdeA skeletal collection. All the trends were no longer significant after the Bonferroni correction and all Cramer's V value were <03.

Table 3-42.Comparison of the presence of asymmetry of EC between the two skeletal collections. Chi-squared test, and Cramer's V results of the entheses in the lower limb by feature.

		Overall				**BF(Z1)**				**ER(Z1)**				**TC**				**BF(Z2)**				**ER(Z2)**				**FPO**				**MPO**			
		NILMFS		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**	
Enthesis		*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**
Iliopsoas	Left side higher	15	14.7	12	17.4	3	3.4	1	2.3	0	0.0	0	0.0	5	5.6	3	6.7	7	7.9	1	2.2	10	11.2	2	4.4	4	4.5	3	6.7	2	2.2	3	6.7
	Equal	68	66.7	47	68.1	82	93.2	42	97.7	89	101.1	45	104.7	79	88.8	41	91.1	69	77.5	41	91.1	73	82.0	40	88.9	75	84.3	40	88.9	86	96.6	41	91.1
	Right side higher	19	18.6	10	14.5	3	3.4	0	0.0	0	0.0	0	0.0	5	5.6	1	2.2	13	14.6	3	6.7	6	6.7	3	6.7	10	11.2	2	4.4	1	1.1	1	2.2
	Total	102		69		88		43		89		45		89		45		89		45		89		45		89		45		89		45	
	Chi-Square	0.62				**2.57**				-				**0.94**				3.84				**1.90**				**2.07**				**1.78**			
	df	2				2				-				2				2				2				2				2			
	p-value	0.735				0.277				-				0.625				0.146				0.387				0.355				0.411			
	Cramer's V	0.06				0.11				-				0.08				0.17				0.11				0.12				0.12			
Gastrocnemius	Left side higher	8	7.8	8	11.6	6	6.5	5	7.9	3	3.3	1	1.6	4	4.3	4	6.2	7	7.6	3	4.6	9	9.8	4	6.2	2	2.2	3	4.6	1	1.1	0	0.0
	Equal	66	64.7	48	69.6	81	88.0	54	85.7	85	92.4	62	98.4	73	79.3	52	80.0	83	90.2	55	84.6	61	66.3	49	75.4	86	93.5	62	95.4	91	98.9	65	100.0
	Right side higher	28	27.5	13	18.8	5	5.4	4	6.3	4	4.3	0	0.0	15	16.3	9	13.8	2	2.2	7	10.8	22	23.9	12	18.5	4	4.3	0	0.0	0	0.0	0	0.0
	Total	102		69		92		63		92		63		92		65		92		65		92		65		92		65		92		65	
	Chi-Square	2.04				**0.18**				**4.75**				**0.39**				**5.64**				1.58				**4.99**				**1.07**			
	df	2				2				2				2				2				2				2				1			
	p-value	0.361				0.913				0.093				0.821				0.06				0.455				0.083				0.3			
	Cramer's V	0.11				0.03				0.15				0.05				0.19				0.1				0.15				0.07			
Quadriceps femoris	Left side higher	25	24.5	11	15.9	9	11.5	8	15.4	3	3.8	1	1.9	10	13.0	3	5.7	8	10.4	8	15.1	4	5.2	4	7.5	2	2.6	0	0.0	1	1.3	0	0.0
	Equal	67	65.7	52	75.4	59	75.6	36	69.2	74	94.9	45	86.5	63	81.8	49	92.5	61	79.2	36	67.9	65	84.4	44	83.0	74	96.1	52	98.1	76	98.7	52	98.1
	Right side higher	10	9.8	6	8.7	10	12.8	8	15.4	1	1.3	6	11.5	4	5.2	1	1.9	8	10.4	9	17.0	8	10.4	5	9.4	1	1.3	1	1.9	0	0.0	1	1.9
	Total	102		69		78		52		78		52		77		53		77		53		77		53		77		53		77		53	
	Chi-Square	2.04				0.68				**6.91**				**3.20**				2.14				**0.31**				**2.18**				**2.84**			
	df	2				2				2				2				2				2				2				2			
	p-value	0.36				0.713				0.032*				0.202				0.342				0.855				0.337				0.241			
	Cramer's V	0.11				0.07				0.23				0.15				0.13				0.05				0.11				0.13			
Vastus lateralis	Left side higher	15	14.7	12	17.4	11	15.1	5	11.1	1	1.4	0	0.0	10	13.9	5	10.9	7	9.7	3	6.5	4	5.6	5	10.9	0	0.0	0	0.0	0	0.0	0	0.0
	Equal	74	72.5	47	68.1	55	75.3	34	75.6	71	97.3	45	100.0	54	75.0	32	69.6	62	86.1	41	89.1	67	93.1	40	87.0	70	97.2	45	97.8	72	100.0	46	100.0
	Right side higher	13	12.7	10	14.5	7	9.6	6	13.3	1	1.4	0	0.0	8	11.1	9	19.6	3	4.2	2	4.3	1	1.4	1	2.2	2	2.8	1	2.2	0	0.0	0	0.0
	Total	102		69		73		45		73		45		72		46		72		46		72		46		72		46		72		46	
	Chi-Square	0.40				0.68				**1.94**				1.80				**0.38**				**1.22**				**0.05**				-			
	df	2				2				2				2				2				2				1				-			
	p-value	0.82				0.713				0.379				0.426				0.826				0.543				0.826				-			
	Cramer's V	0.05				0.08				0.1				0.12				0.06				0.1				0.02				-			

** Indicated significance at 0.05 level. Bold numbers indicated that assumptions of the Pearson Chi squared test were violated, and Likelihood-ratio was used. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity.*

Continuation table 3.49. Comparison of the presence of asymmetry of EC between the two skeletal collections. Chi-squared test, and Cramer's V results of the entheses in the lower limb by feature.

		Overall				**BF(Z1)**				**ER(Z1)**				**TC**				**BF(Z2)**				**ER(Z2)**				**FPO**				**MPO**			
		NILMFS		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**	
Enthesis		*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**
Patella ligament	Left side higher	8	7.8	7	10.1	9	9.8	4	7.5	5	5.4	2	3.8	7	8.0	1	1.8	7	8.0	2	3.6	7	8.0	0	0.0	4	4.6	1	1.8	0	0.0	0	0.0
	Equal	82	80.4	53	76.8	71	77.2	42	79.2	82	89.1	51	96.2	68	78.2	50	90.9	72	82.8	45	81.8	76	87.4	53	96.4	78	89.7	52	94.5	84	96.6	54	98.2
	Right side higher	12	11.8	9	13.0	12	13.0	7	13.2	5	5.4	0	0.0	12	13.8	4	7.3	8	9.2	8	14.5	4	4.6	2	3.6	5	5.7	2	3.6	3	3.4	1	1.8
	Total	102		69		92		53		92		53		87		55		87		55		87		55		87		55		87		55	
	Chi-Square	0.37				0.21				**4.93**				**4.73**				1.89				**7.23**				**1.22**				**0.44**			
	df	2				2				2				2				2				2				2				1			
	p -value	0.831				0.902				0.085				0.094				0.388				0.027*				0.544				0.505			
	Cramer's V	0.05				0.04				0.15				0.17				0.12				0.18				0.09				0.05			
Triceps surae	Left side higher	10	9.8	8	11.6	7	7.8	4	7.3	6	6.7	1	1.8	4	4.6	2	3.4	14	16.1	9	15.5	7	8.0	1	1.7	7	8.0	2	3.4	3	3.4	0	0.0
	Equal	86	84.3	53	76.8	76	84.4	48	87.3	80	88.9	54	98.2	78	89.7	46	79.3	63	72.4	45	77.6	77	88.5	52	89.7	73	83.9	55	94.8	83	95.4	57	98.3
	Right side higher	6	5.9	8	11.6	7	7.8	3	5.5	4	4.4	0	0.0	5	5.7	10	17.2	10	11.5	4	6.9	3	3.4	5	8.6	7	8.0	1	1.7	1	1.1	1	1.7
	Total	102		69		90		55		90		55		87		58		87		58		87		58		87		58		87		58	
	Chi-Square	**2.05**				0.32				**6.05**				**4.89**				0.89				**4.60**				**4.70**				**3.18**			
	df	2				2				2				2				2				2				2				2			
	p -value	0.359				0.852				0.049*				0.087				0.639				0.1				0.095				0.204			
	Cramer's V	0.11				0.05				0.18				0.19				0.08				0.17				0.17				0.12			
Plantar fascia	Left side higher	-	-	-	-	11	10.8	15	21.7	0	0.0	0	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Equal	-	-	-	-	80	78.4	46	66.7	102	100.0	69	100.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Right side higher	-	-	-	-	11	10.8	8	11.6	0	0.0	0	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total	-		-		102		69		102		69		-		-		-		-		-		-		-		-		-		-	
	Chi-Square	-				**4.05**				-				-				-				-				-				-			
	df	-				2				-				-				-				-				-				-			
	p -value	-				0.132				-				-				-				-				-				-			
	Cramer's V	-				0.15				-				-				-				-				-				-			

** Indicates significance at 0.05 level. Bold numbers indicate that assumptions of the Pearson Chi squared test were violated, and Likelihood-ratio was used. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity.*

Table 3-43. Comparison of the presence of asymmetry of EC between the two skeletal collections. Chi-squared test, and Cramer's V results of the joint complexes of the lower limb by feature.

		Overall				**BF(Z1)**				**ER(Z1)**				**TC**				**BF(Z2)**				**ER(Z2)**				**FPO**				**MPO**			
		NILMFS		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**	
Enthesis		*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**	*f*	**%**
Knee	Left side higher	5	6.4	2	3.6	6	5.9	6	8.7	9	8.8	3	4.3	14	13.7	12	17.4	14	13.7	10	14.5	14	13.7	6	8.7	8	7.8	4	5.8	1	1.0	0	0.0
	Equal	66	84.6	49	89.1	85	83.3	53	76.8	86	84.3	58	84.1	74	72.5	45	65.2	70	68.6	42	60.9	76	74.5	55	79.7	87	85.3	62	89.9	98	96.1	67	97.1
	Right side higher	7	9.0	4	7.3	11	10.8	10	14.5	7	6.9	8	11.6	14	13.7	12	17.4	18	17.6	17	24.6	12	11.8	8	11.6	7	6.9	3	4.3	3	2.9	2	2.9
	Total	78		55		102		69		102		69		102		69		102		69		102		69		102		69		102		69	
	Chi-Square	**0.68**				1.14				2.23				1.05				1.38				1.04				**0.81**				**1.04**			
	df	2				2				2				2				2				2				2				2			
	p-value	0.711				0.565				0.329				0.593				0.502				0.596				0.667				0.595			
	Cramer's V					0.08				0.11				0.08				0.09				0.08				0.07				0.06			
Ankle/foot	Left side higher	3	3.6	4	7.3	10	9.8	8	11.6	8	7.8	2	2.9	7	6.9	4	5.8	21	20.6	7	10.1	15	14.7	3	4.3	6	5.9	2	2.9	4	3.9	0	0.0
	Equal	77	92.8	52	94.5	81	79.4	57	82.6	88	86.3	67	97.1	80	78.4	52	75.4	72	70.6	53	76.8	64	62.7	54	78.3	85	83.3	66	95.7	97	95.1	67	97.1
	Right side higher	3	3.6	4	7.3	11	10.8	4	5.8	6	5.9	0	0.0	15	14.7	13	18.8	9	8.8	9	13.0	23	22.5	12	17.4	11	10.8	1	1.4	1	1.0	2	2.9
	Total	83		60		102		69		102		69		102		69		102		69		102		69		102		69		102		69	
	Chi-Square	**1.45**				1.41				**8.62**				0.55				3.66				6.17				**7.83**				**5.00**			
	df	2				2				2				2				2				2				2				2			
	p-value	0.485				0.495				**0.013**				0.759				0.161				**0.046**				**0.02**				0.082			
	Cramer's V	0.1				0.09				0.19				0.06				0.15				0.19				0.2				0.15			

** Indicates significance at 0.05 level. Bold numbers indicate that assumptions of the Pearson Chi squared test were violated, and Likelihood-ratio was used. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity.*

3.2.2.2.3.2. Asymmetry by age range

The bilateral asymmetries of the entheses on the lower limbs were reported by each age category and feature (see Appendix 5). The comparison of the overall asymmetries between the two skeletal collections evidenced that the UdeA skeletal collection had a higher frequency of bilateral asymmetry than the NILMFS skeletal collection in most entheses (78%), which is the opposite trend from the bilateral asymmetry observed in the upper limbs. The results of the Chi squared test showed that the differences between the two skeletal collections were significant in only two cases, the left-side asymmetry of the *quadriceps femoris* of the young adult category and the left-side asymmetry of the gastrocnemius enthesis of middle adults (Table 3-44). In both cases, the highest frequencies of EC were observed in the left-side asymmetry of the NILMFS skeletal collection. These differences remained significant after the Bonferroni correction, and both had medium effect size.

The Chi squared test showed that the asymmetry trends by features were similar within the two skeletal collections, except for the presence of fine porosity in the patellar ligament insertion of the young adults, erosion (Z2) in the *triceps surae* insertion and bone formation (Z1) in the plantar fascia origin of the old adults. The UdeA skeletal collection showed no cases of asymmetry in fine porosity, while the NILMFS skeletal collection reported 15.6% individuals with either left-side or right-side asymmetry. Erosion (Z2) in the *triceps surae* was frequent in the right side of the old adults from the UdeA skeletal collection (13.3%) and no cases were found in the right side of individuals from the NILMFS skeletal collection. Bone formation (Z1) was often seen in the left side of the old adults from the UdeA skeletal collection (53%), compared to the frequency observed in the old adults from the NILMFS skeletal collection (12.5%). Only the differences in the presence of bone formation (Z1) between the two skeletal collections remained significant after the Bonferroni correction. The differences observed between the old adults of the two skeletal collections had medium effect size.

3.2.2.2.3.3. Asymmetry by joint complex and age range

The overall frequencies of the knee and the ankle/foot joint complexes of the lower limbs showed that the young adults of both skeletal collections had the highest frequencies within the three age categories, except for the knee of the UdeA skeletal collection in which the old adults had the most asymmetry (Table 3-45). Yet, the difference of these trends was not statistically significant. The Chi squared test compared the asymmetry trends by features within each age range. The results showed that the asymmetry of the presence of erosion (Z2) of the knee joint complex was different within the old adults of the two skeletal collections. In these individuals, the left-side asymmetry found in the NILMFS skeletal collection was greater than that observed in the UdeA skeletal collection. The same joint complex evidenced that asymmetry was rare in the old adults of the UdeA skeletal collection. This difference remained significant after the Bonferroni correction, but the effect size was small

The ankle and foot joint complex evidenced that the presence of bone formation(Z2) and fine porosity of the middle adults were different between the two skeletal collections. Bone formation (Z2) was frequent in the left side of the individuals from the NILMFS skeletal collection, while the individuals from the UdeA skeletal collection evidenced that asymmetry of this feature was uncommon. Low proportions of fine porosity asymmetry were also observed in the individuals from the UdeA skeletal collection and high frequency of right-side asymmetry in the individuals from the NILMFS skeletal collection. Both trends were no longer significant after the Bonferroni correction. Nevertheless, all three features had a medium effect size.

Table 3-44. Chi squared test and Cramer's V comparing asymmetry of EC presence between the two skeletal collections by enthesis, age range, and feature.

Enthesis	Test		Overall	BF(Z1)	ER(Z1)	TC	BF(Z2)	ER(Z2)	FPO	MPO
Iliopsoas	Chi-square test	Young adult	1.81	1.40	1.40	1.35	4.01	0.82	1.46	2.64
		df	2	2	1	2	2	2	2	1
		p-value	0.404	0.495	0.236	0.510	0.135	0.665	0.483	0.104
		Cramer's V	0.16	0.13	0.13	0.15	0.22	0.12	0.15	0.18
		Middle adult	0.11	0.06	2.50	2.13	4.04	0.65	0.71	3.16
		df	2	2	1	2	2	2	1	2
		p-value	0.945	0.970	0.114	0.344	0.133	0.724	0.399	0.206
		Cramer's V	0.05	0.04	0.24	0.21	0.32	0.12	0.10	0.25
		Old adult	1.91	2.55	2.40	5.86	0.94	0.19	0.77	2.40
		df	2	2	2	2	2	2	2	2
		p-value	0.385	0.279	0.302	0.053	0.631	0.913	0.379	0.302
		Cramer's V	0.21	0.24	0.19	0.33	0.15	0.07	0.11	0.19
Gastrocnemius	Chi-square test	Young adult	4.47	4.78	-	1.78	5.55	0.50	1.59	-
		df	2	2	-	2	2	2	2	-
		p-value	0.107	0.092	-	0.41	0.062	0.78	0.452	-
		Cramer's V	0.22	0.24	-	0.15	0.25	0.09	0.14	-
		Middle adult	8.44	1.01	2.11	1.77	1.92	4.72	2.04	-
		df	2	1	2	2	2	2	1	-
		p-value	**0.015***	0.316	0.347	0.412	0.382	0.095	0.153	-
		Cramer's V	0.37	0.12	0.18	0.19	0.19	0.3	0.17	-
		Old adult	0.19	0.35	2.88	1.29	5.92	2.10	0.74	0.74
		df	2	2	2	2	2	2	1	1
		p-value	0.908	0.839	0.237	0.525	0.060	0.351	0.391	0.391
		Cramer's V	0.07	0.09	0.20	0.16	0.35	0.22	0.10	0.10
Quadriceps femoris	Chi-square test	Young adult	10.39	2.96	1.37	5.02	3.09	4.23	2.78	-
		df	2	2	2	2	2	2	2	-
		p-value	**0.006***	0.228	0.505	0.081	0.213	0.121	0.25	-
		Cramer's V	0.33	0.20	0.16	0.26	0.23	0.23	0.19	-
		Middle adult	3.03	0.10	4.77	4.45	0.30	0.19	-	-
		df	2	2	2	2	2	1	-	-
		p-value	0.220	0.950	0.092	0.108	0.862	0.667	-	-
		Cramer's V	0.24	0.06	0.33	0.29	0.09	0.07	-	-
		Old adult	4.13	1.59	2.85	1.22	3.10	1.38	1.22	3.35
		df	2	2	1	1	2	2	2	2
		p-value	0.127	0.451	0.091	0.269	0.212	0.503	0.543	0.187
		Cramer's V	0.29	0.21	0.28	0.14	0.30	0.15	0.14	0.29

** Indicates significance at 0.05 level. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation, ER(Z2)=erosion, FPO =fine porosity, MPO= macro-porosity.*

Continuation Table 3-54. Chi squared test and Cramer's V comparing asymmetry of EC presence between the two skeletal collections by enthesis, age range, and feature.

Enthesis	**Test**		**Overall**	**BF(Z1)**	**ER(Z1)**	**TC**	**BF(Z2)**	**ER(Z2)**	**FPO**	**MPO**
Vastus lateralis	Chi-square test	Young adult	2.16	2.59	2.94	0.32	4.49	1.05	0.19	-
		df	2	2	2	2	2	1	1	-
		p-value	0.339	0.274	0.230	0.852	0.106	0.306	0.593	-
		Cramer's V	0.17	0.22	0.21	0.08	0.26	0.14	0.07	-
		Middle adult	1.90	3.02	-	3.12	1.49	3.36	-	-
		df	2	2	-	2	2	2	-	-
		p-value	0.386	0.22	-	0.21	0.474	0.187	-	-
		Cramer's V	0.19	0.26	-	0.31	0.22	0.31	-	-
		Old adult	0.70	3.56	-	0.06	2.29	1.76	-	-
		df	2	2	-	2	2	2	-	-
		p-value	0.706	0.169	-	0.970	0.318	0.416	-	-
		Cramer's V	0.12	0.29	-	0.04	0.21	0.17	-	-
Patella ligament	Chi-square test	Young adult	0.40	1.55	1.12	4.38	2.52	3.81	6.51	1.47
		df	2	2	1	2	2	2	2	1
		p-value	0.817	0.460	0.291	0.112	0.284	0.149	**0.039**	0.226
		Cramer's V	0.08	0.16	0.11	0.23	0.17	0.21	0.28	0.13
		Middle adult	1.77	0.66	0.82	3.86	1.41	2.93	0.17	0.97
		df	2	2	2	2	2	2	2	1
		p-value	0.412	0.72	0.662	0.145	0.495	0.231	0.92	0.324
		Cramer's V	0.18	0.12	0.11	0.29	0.19	0.24	0.07	0.12
		Old adult	0.73	2.40	3.25	3.71	1.93	4.00	3.10	1.58
		df	2	2	2	2	2	2	2	1
		p-value	0.695	0.301	0.197	0.157	0.382	0.135	0.212	0.209
		Cramer's V	0.12	0.19	0.22	0.25	0.18	0.25	0.25	0.15
Triceps surae	Chi-square test	Young adult	4.95	0.36	3.79	2.47	3.46	5.16	2.71	4.11
		df	2	2	2	2	2	2	2	2
		p-value	0.084	0.836	0.15	0.291	0.177	0.076	0.258	0.128
		Cramer's V	0.25	0.08	0.22	0.19	0.21	0.26	0.18	0.22
		Middle adult	1.44	3.07	1.58	2.25	2.27	1.87	5.23	0.82
		df	2	2	2	2	2	2	2	1
		p-value	0.486	0.215	0.455	0.325	0.321	0.392	0.073	0.364
		Cramer's V	0.17	0.24	0.15	0.22	0.22	0.17	0.3	0.11
		Old adult	5.02	1.95	1.95	3.00	0.78	6.79	1.05	0.87
		df	2	2	2	2	2	2	2	1
		p-value	0.081	0.377	0.377	0.224	0.676	**0.033**	0.592	0.351
		Cramer's V	0.26	0.17	0.17	0.27	0.14	0.35	0.13	0.11
Plantar fascia	Chi-square test	Young adult	-	0.20	-	-	-	-	-	-
		df	-	2	-	-	-	-	-	-
		p-value	-	0.905	-	-	-	-	-	-
		Cramer's V	-	0.05	-	-	-	-	-	-
		Middle adult	-	0.60	-	-	-	-	-	-
		df	-	2	-	-	-	-	-	-
		p-value	-	0.742	-	-	-	-	-	-
		Cramer's V	-	0.11	-	-	-	-	-	-
		Old adult	-	8.94	-	-	-	-	-	-
		df	-	2	-	-	-	-	-	-
		p-value	-	**0.011***	-	-	-	-	-	-
		Cramer's V	-	0.44	-	-	-	-	-	-

** Indicates significance at 0.05 level. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation, ER(Z2)=erosion, FPO =fine porosity, MPO= macro-porosity.*

Table 3-45. Chi squared test and Cramer's V comparing asymmetry of EC presence between the two skeletal collections by enthesis, age ranges and feature.

Joint	Test		Overall	BF(Z1)	ER(Z1)	TC	BF(Z2)	ER(Z2)	FPO	MPO
Knee	Chi-square test	Young adult	1.54	0.80	2.96	0.56	0.01	3.99	1.98	1.43
		df	2	2	2	2	2	2	2	1
		p -value	0.462	0.671	0.228	0.756	0.997	0.136	0.372	0.232
		Cramer's V	0.15	0.11	0.20	0.09	0.01	0.23	0.16	0.12
		Middle adult	1.80	0.57	4.62	1.75	1.91	1.48	0.39	0.90
		df	2	2	2	2	2	2	2	1
		p -value	0.407	0.752	0.099	0.417	0.386	0.478	0.825	0.343
		Cramer's V	0.17	0.11	0.30	0.18	0.19	0.17	0.09	0.10
		Old adult	5.06	1.92	0.82	0.19	1.97	9.06	1.58	0.78
		df	2	2	2	2	2	2	2	2
		p -value	0.08	0.384	0.665	0.912	0.373	**0.011***	0.454	0.677
		Cramer's V	0.37	0.21	0.13	0.06	0.21	0.36	0.14	0.1
Ankle/foot	Chi-square test	Young adult	2.00	0.26	4.20	4.21	0.39	2.55	4.62	5.55
		df	2	2	2	2	2	2	2	2
		p -value	0.367	0.879	0.122	0.122	0.822	0.28	0.099	0.062
		Cramer's V	0.17	0.06	0.21	0.23	0.07	0.18	0.22	0.24
		Middle adult	1.06	2.77	1.84	2.19	7.91	4.83	6.89	0.90
		df	2	2	2	2	2	2	2	1
		p -value	0.588	0.251	0.398	0.335	**0.019**	0.089	**0.032**	0.343
		Cramer's V	0.13	0.23	0.15	0.19	0.32	0.28	0.29	0.10
		Old adult	0.80	5.94	2.94	3.28	1.99	5.76	1.83	1.58
		df	1	2	2	2	2	2	2	2
		p -value	0.372	0.051	0.23	0.194	0.37	0.056	0.401	0.454
		Cramer's V	0.12	0.27	0.21	0.21	0.21	0.29	0.16	0.14

** Indicates significance at 0.05 level. Bold numbers indicate that assumptions of the Pearson Chi squared test were violated, and Likelihood-ratio was used. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation, ER(Z2)=erosion, FPO =fine porosity, MPO= macro-porosity.*

3.3. Objective 2. Antemortem trauma and entheseal changes.

3.3.1. Descriptive and inferential statistics

Skeletal evidence of trauma was recorded as healed fracture, stress fracture, secondary osteoarthritis, myositis ossificans or dislocation. All the skeletal evidence of antemortem trauma was pooled into hard tissue and soft tissue categories (see Chapter 2). Except for the categories of “healed fractures” and “myositis ossificans”, all the other categories had small sample size i.e., between 0 and 2 cases. As expected, (Table 3-46), the overall frequencies of the hard tissue category (68%) were higher than the soft tissue category (32%). The skeletal evidence of the hard tissue category was more frequent than the soft tissue category in all the bones, except for the scapula and femur which evidenced the same frequency in both types of injuries. The frequencies in the upper limbs showed that the humerus was the bone with most evidence of hard tissue injuries, while the ulna was the bone with the highest frequencies of soft tissue trauma. The lower limbs showed that tibia had the most frequency of hard tissue injuries, while soft tissue injuries were most common in both the tibia and the femur.

Similar trends of overall frequencies of both the hard and soft tissue were observed in each of the skeletal collections, in which most injuries were categorized as hard tissue and are located in the lower limbs (hard tissue 41%; soft tissue 23%). Similar to overall trends, femur and tibia were the bones showing the highest frequencies in both categories within the lower limbs. The humerus, ulna, and radius showed the same trend in the upper limbs, which differs from the clinical statistics reported for Medellin (Table 1-3), where fractures of the bones of the wrist and hands were more common

Table 3-46. Frequencies of antemortem injuries pooled into hard and soft tissue.

		NILMFS				UdeA				Total sample			
		Hard tissue		Soft tissue		Hard tissue		Soft tissue		Hard tissue		Soft tissue	
Anatomical region	**Bone**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**
	Skull	3	2%							3	2%	0	0%
	Subtotal	3	2%							3	2%	0	0%
Upper limbs	Clavicle					1	1%			1	1%	0	0%
	Scapula	2	1%	2	1%	1	1%	1	1%	3	2%	3	2%
	Humerus	3	2%	2	1%	7	5%	1	1%	10	7%	3	2%
	Radius	6	4%			3	2%	1	1%	9	7%	1	1%
	Ulna	4	3%	2	1%	3	2%	3	2%	7	5%	5	4%
	Metacarpals	2	1%			2	1%			4	3%	0	0%
	Subtotal	17	12%	6	4%	17	12%	6	4%	34	25%	12	9%
Lower limbs	Os coxae	3	2%	1	1%					3	2%	1	1%
	Femur	5	4%	7	5%	7	5%	5	4%	12	9%	12	9%
	Patella	2	1%			1	1%	1	1%	3	2%	1	1%
	Tibia	12	9%	7	5%	8	6%	5	4%	20	15%	12	9%
	Fibula	6	4%	1	1%	1	1%			7	5%	1	1%
	Calcaneus	4	3%	2	1%	2	1%	2	1%	6	4%	4	3%
	Tarsus	4	3%	1	1%	1	1%			5	4%	1	1%
	Subtotal	36	26%	19	14%	20	15%	13	9%	56	41%	32	23%
										0	0%	0	0%
Overall	Total	56	41%	25	18%	37	27%	19	14%	93	68%	44	32%

Percentage was calculated based on the total number of injuries recorded (137).

Skeletal evidence consistent with antemortem injuries were frequently observed in both skeletal collections. A total of 137 antemortem injuries were recorded in 78 individuals (45.6% skeletons of the total sample) and were summarized by bone and side (Table 3-47). Of those, 48 individuals belonged to the NILMFS skeletal collection, and 30 individuals were part of the UdeA skeletal collection. Chi squared test showed no significant association between the skeletal collections and the presence of traumatic injuries, X^2 (1, N=171) =0.213, p=.645.

Table 3-47. Distribution of the presence of antemortem injuries recorded in the total sample by bone and side.

Anatomical region	Bone	Left			Right			Total		
		N	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**
	Skull								3	1.8%
	Subtotal							171	3	1.8%
Upper limbs	Clavicle					1	0.6%		1	0.3%
	Scapula		3	1.8%		3	1.8%		6	1.8%
	Humerus		5	2.9%		8	4.7%		13	3.8%
	Ulna		6	3.5%		6	3.5%		12	3.5%
	Radius		4	2.4%		6	3.5%		10	2.9%
	Metacarpals					4	2.3%		4	1.2%
	Subtotal	170	18	10.6%	171	28	16.4%	341	46	13.5%
Lower limbs	Os coxae					4	2.4%		4	1.2%
	Femur		15	8.9%		9	5.3%		24	7.1%
	Patella		1	0.6%		3	1.8%		4	1.2%
	Fibula		5	3.0%		3	1.8%		8	2.4%
	Tibia		17	10.1%		15	8.9%		32	9.5%
	Calcaneus		4	2.4%		6	3.6%		10	3.0%
	Tarsals		4	2.4%		2	1.2%		6	1.8%
	Subtotal	168	46	27.4%	169	42	24.9%	337	88	26.1%
Total		338	64	18.9%	340	70	20.6%	678	137	20.2%

Unlike the clinical statistics reported for Santa Marta, antemortem injuries were more frequent in the lower limbs than the upper limbs. The femur and tibia showed the most injuries of all. In the upper limbs, injuries were mostly located in the humerus, ulna, and radius. Chi squared test showed that the presence of antemortem injuries was different between the two anatomical regions, X^2 (1, N=678) =11.65, p=.001. However, the difference has a Cramer's V value <0.2.

The overall trends in the upper limbs showed that the right side had more injuries than the left side, but this difference was not statistically significant, X^2 (1, N=341) =1.05, *p*=.305. The antemortem traumatic injuries observed in the right side were in six different bones, while the injuries in the left side were focused in only four bones. The overall frequencies of the injuries in the lower limbs showed that in the left side six different bones were affected by trauma, while in the right side seven different bones were affected. Therefore, the difference between sides was not statistically significant, X^2 (1, N=337) =0.16, *p*=.689.

The frequencies of overall presence were reduced to 4.6% when percentage of trauma was calculated by bone[3] and not by individual. All cases were summarized by anatomical region, bone, and side (Table 3-48). Chi squared test showed association between bone and presence of traumatic injuries in both the right, X^2 (6, N=1144) =12.76, *p*=<.0001, Cramer's *V*=.16, and the left side, X^2 (6, N=1142) =27.93, *p*=<.0047, Cramer's *V*=.11. However, the effect size of these associations was small.

Table 3-48. Overall frequencies of antemortem trauma injuries by bone and side.

Anatomical region	**Bone**	**Left** **N**	**f**	**%**	**Right** **N**	**f**	**%**	**Overall** **N**	**f**	**%**
Upper limbs	Humerus	168	5	3.0%	169	8	4.7%	337	13	3.9%
	Ulna	156	6	3.8%	156	6	3.8%	312	12	3.8%
	Radius	166	4	2.4%	169	6	3.6%	335	10	3.0%
	Subtotal	490	15	3.1%	494	20	4.0%	984	35	3.6%
Lower limbs	Femur	168	15	8.9%	168	9	5.4%	336	24	7.1%
	Patella	152	1	0.7%	149	3	2.0%	301	4	1.3%
	Tibia	165	17	10.3%	166	15	9.0%	331	32	9.7%
	Calcaneus	167	4	2.4%	167	6	3.6%	334	10	3.0%
	Subtotal	652	37	5.7%	650	33	5.1%	1302	70	5.4%
Total		1142	52	4.6%	1144	53	4.6%	2286	105	4.6%

General trends of the frequencies by bone were like those observed in the frequencies by individual, where the overall frequencies of the upper limbs were significantly lower than the lower limbs, but the difference had a small effect, X^2 (1, N=2286) =6.199, *p*=.013, *Cramer's V=.05*. The upper limbs showed higher frequencies in the right side than the left side, and the opposite trend was evidenced in the lower limbs, i.e., the left side showed higher frequencies than the right side. The percentage of overall trauma by bone was also similar between both skeletal collections (NILMFS= 5%, UdeA= 4%), therefore the difference of frequencies by bone was not statistically significant, X^2 (1, N=2286) =0.913, *p*=.339.

Overall presence of trauma was summarized by age groups (*mean*=45,6%, *SD*=1,3%). The percentage of trauma ranged from 44,7% to 47,2% (Table 3-49), where the old adult group showed the lowest frequencies, and the middle adult group had the highest value of all. No

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[3] The bones used to calculate the overall percentage were those in which the entheses under analysis are located, i.e., humerus, radius, ulna, femur, patella, tibia and calcaneus.

statistically significant differences were observed in the frequencies of overall traumatic injuries within the age groups, X^2 (2, N=171) =0,077, *p*=,962.

Table 3-49. Overall trauma presence by age groups

Age range	N	f	%
Young adult	71	32	45.1%
Middle adult	53	25	47.2%
Old adult	47	21	44.7%
Total	171	78	45.6%

3.3.1.1. *UdeA skeletal collection*

The total sample of the UdeA skeletal collection included 69 individuals, of these 30 individuals (43.5%) showed skeletal features consistent with traumatic injuries. A total of 56 traumatic injuries were recorded in the entire skeleton (Table 3-50). The general trends of the UdeA skeletal collection followed the same trends as the overall distribution of traumatic injuries, but differ from the clinical statistics reported for Medellin, in which the lower limbs were more affected than the upper limbs, but the difference between limbs was not statistically significant, X^2 (1, N=276) =1.81, *p*=.179. The right upper limb showed more injuries than the left side, while the right lower limb evidenced less traumatic injuries than the left side. Chi squared test showed that the traumatic injuries were not associated to the left or right side in the upper limbs, X^2 (1, N=138) =1.88, *p*=.170. The same was true for the lower limbs, X^2 (1, N=138) =2.55, *p*=.110.

Frequencies by bone and side showed that skeletal evidence of traumatic injuries were observed in 5.1% of the bones sampled in this skeletal collection (Table 3-51). General trends of the upper and lower limbs of the UdeA skeletal collection were consistent to those observed in the overall sample, except for the frequencies of the humerus (7.2%) that showed the greatest frequencies of traumatic injuries within all bones of the right side. However, the clinical records reported that the bones of the hand and wrist were the most frequent fractures treated in the emergency room in Medellin. Although the upper limbs showed higher presence of traumatic injuries than the lower limbs, the difference between both anatomical regions was not significant, X^2 (1, N=917) =0.177, *p*=.674.

Table 3-50. Distribution of the traumatic injuries recorded in the UdeA skeletal collection.

Anatomical region	**Bone**	Left			Right			Total		
		N	f	%	N	f	%	N	f	%
Upper limbs	Clavicle					1	1.4%		1	0.7%
	Scapula					2	2.9%		2	1.4%
	Humerus		3	4.3%		5	7.2%		8	5.8%
	Ulna		3	4.3%		3	4.3%		6	4.3%
	Radius		2	2.9%		2	2.9%		4	2.9%
	Metacarpals					2	2.9%		2	1.4%
	Subtotal	69	8	11.6%	69	15	21.7%	138	23	16.7%
Lower limbs	Femur		8	11.6%		4	5.8%		12	8.7%
	Patella					2	2.9%		2	1.4%
	Fibula					1	1.4%		1	0.7%
	Tibia		9	13.0%		4	5.8%		13	9.4%
	Calcaneus		3	4.3%		1	1.4%		4	2.9%
	Tarsals		1	1.4%					1	0.7%
	Subtotal	69	21	30.4%	69	12	17.4%	138	33	23.9%
Total		138	29	21.0%	138	27	19.6%	276	56	20.3%

Table 3-51. Frequencies of antemortem trauma injuries by bone and side in the UdeA skeletal collection.

Anatomical region	**Bone**	**Left**			**Right**			**Overall**		
		N	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**
Upper limbs	Humerus	67	3	4.5%	69	5	7.2%	136	8	5.9%
	Ulna	61	3	4.9%	58	3	5.2%	119	6	5.0%
	Radius	66	2	3.0%	67	2	3.0%	133	4	3.0%
	Subtotal	194	8	4.1%	194	10	5.2%	388	18	4.6%
Lower limbs	Femur	69	7	10.1%	69	4	5.8%	138	11	8.0%
	Patella	62	0	0.0%	61	2	3.3%	123	2	1.6%
	Tibia	67	8	11.9%	66	4	6.1%	133	12	9.0%
	Calcaneus	68	3	4.4%	67	1	1.5%	135	4	3.0%
	Subtotal	266	18	6.8%	263	11	4.2%	529	29	5.5%
Total		460	26	5.7%	457	21	4.6%	917	47	5.1%

The trends of the “hard tissue” and the “soft tissue” frequencies were consistent with the overall trends, with the exception of the distribution of the soft tissue injuries in the upper limbs, in which the radius had the most injuries of all (Table 3-52). The hard tissue category evidenced more injuries than the soft tissue category in all the bones.

Table 3-52. Frequencies of traumatic injuries within soft tissue and hard tissue categories. UdeA skeletal collection.

Anatomical region	**Bone**	**N**	**Hard tissue**		**Soft tissue**	
			f	**%**	**f**	**%**
Upper limbs	Humerus	136	7	5.1%	1	0.7%
	Radius	119	3	2.5%	3	2.5%
	Ulna	133	3	2.3%	1	0.8%
	Subtotal	388	13	3.4%	5	1.3%
Lower limbs	Femur	138	6	4.3%	5	3.6%
	Patella	123	1	0.8%	1	0.8%
	Tibia	133	7	5.3%	5	3.8%
	Calcaneus	135	2	1.5%	2	1.5%
	Subtotal	529	16	3.0%	13	2.5%
Overall	Total	917	29	3.2%	18	2.0%

The trends of traumatic injuries within the three age groups (*M*=43.9%, *SD*=2.4%) in the UdeA skeletal collection were different from the overall percentage by age groups (Table 3-53). Percentages ranged from 42.1% to 46.7%, with the old adult group showing the highest frequencies of trauma. Chi squared test showed that the difference of the presence of traumatic injuries between the age groups was not significant, X^2 (2, N=69) =0.082, *p*=.96. The general trends of the frequencies of traumatic injuries by bone in the UdeA skeletal collection (Table 3-54) were different than trends by individual in the same collection. In the former, the middle adult group tended to have more injuries by individual, the latter showed that the old adult group evidenced more individuals exhibiting presence of antemortem trauma.

Table 3-53. Distribution of the presence of trauma in individuals by age groups, UdeA skeletal collection

Age range	N	f	%
Young adult	35	15	42.9%
Middle adult	19	8	42.1%
Old adult	15	7	46.7%
Total	69	30	43.5%

Table 3-54. Frequencies of trauma presence within age groups by bone. UdeA skeletal collection.

	Young adult			Middle adult			Old adult			Total			Chi-squared test		
Side	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**Value**	**df**	**p**
Left	236	15	6.4%	129	7	5.4%	95	4	4.2%	460	26	5.7%	0.602	2	0.74
Right	232	9	3.9%	132	8	6.1%	93	4	4.3%	457	21	4.6%	0.936	2	0.626
Total	468	24	5.1%	261	15	5.7%	188	8	4.3%	917	47	5.1%	0.5	2	0.779

Occupations are one of the main physical activities carried out by male individuals that involve a certain level of risk of a traumatic incident (see chapter 2). The last known occupation of 48 individuals from the UdeA skeletal collection were categorized into "high risk" and "low risk" occupations and compared with the overall presence and absence of trauma (Table 3-55). The results showed that presence of trauma was not associated with an occupation's level of risk, X^2 (1, N=48) =2.239, *p*=.135.

Table 3-55. Crosstabs of level of risk of occupation and overall trauma presence.

	Trauma overall		
Risk occupation	**Absent**	**Present**	**Total**
Low-risk	20	9	29
High-risk	9	10	19
Total	29	19	48

3.3.1.2. *NILMFS skeletal collection*

A total of 81 traumatic injuries were recorded in 48 individuals (47.1%) of the sample from the NILMFS skeletal collection (Table 3-56). The general trends of this skeletal collection showed that the lower limbs were more affected by the traumatic injuries than the upper limbs, but the size of the difference between upper and lower limbs was small, X^2 (1, N=404) =15.65, p=<.001, Cramer's V= *.20.* The right side of the upper limbs had higher frequencies than the left side, but chi-squared results showed that this difference was not significant, X^2 (1, N=203) =0.17, p=.680. The same was true for the lower limbs, X^2 (1, N=201) =0.46, p=.498.

Table 3-56. Distribution of the traumatic injuries recorded in the NILMFS skeletal collection.

Anatomical region	**Bone**	**Left N**	**f**	**%**	**Right N**	**f**	**%**	**Total N**	**f**	**%**
	Skull								3	1.5%
Upper limbs	Scapula		3	3.0%		1	1.0%		4	2.0%
	Humerus		2	2.0%		3	2.9%		5	2.5%
	Ulna		3	3.0%		3	2.9%		6	3.0%
	Radius		2	2.0%		4	3.9%		6	3.0%
	Metacarpals					2	2.0%		2	1.0%
	Subtotal	101	10	9.9%	102	13	12.7%	203	23	11.3%
Lower limbs	Os coxae					4	4.0%		4	2.0%
	Femur		7	6.9%		5	5.0%		12	6.0%
	Patella		1	1.0%		1	1.0%		2	1.0%
	Fibula		5	5.0%		2	2.0%		7	3.5%
	Tibia		8	7.9%		11	11.0%		19	9.5%
	Calcaneus		1	1.0%		5	5.0%		6	3.0%
	Tarsals		3	3.0%		2	2.0%		5	2.5%
	Subtotal	101	25	24.8%	100	30	30.0%	201	55	27.4%
Total		202	35	17.3%	202	43	21.3%	404	81	20.0%

The frequencies of traumatic injuries by bone and side in the sample of the NILMFS skeletal collection (Table 3-57) showed the same trends as the frequencies by individual. The upper limbs (2.9%) evidenced a significantly lower percentage than the lower limbs (5.3%), but the effect size was small, X^2 (1, N=1369) =4.4, p=.036, Cramer's V=*.06.* The percentage of the lower limbs showed higher frequencies of traumatic injuries in the right side than the left side. The frequencies observed in the lower limbs of the NILMFS skeletal collection differ from the overall percentage due to the presence of traumatic injuries in the right tibia and calcaneus. Chi-squared results showed that presence of traumatic injuries and bone were associated in both the left, X^2 (6, N=682) =15.317, p=.018, Cramer's V=*.16* and the right side, X^2 (6, N=687) =13.598, p=.034, Cramer's V=*.15*. However, the effect size values of both sides were small.

Table 3-57. Frequencies of the traumatic injuries by bone and side in the NILMFS skeletal collection.

		Left			**Right**			**Total**		
Anatomical region	**Bone**	N	**f**	**%**	N	**f**	**%**	**N**	**f**	**%**
	Skull							102	3	2.9%
	Subtotal							102	3	2.9%
Upper limbs	Humerus	101	2	1.2%	100	3	1.8%	201	5	2.5%
	Ulna	95	3	1.8%	98	3	1.8%	193	6	3.1%
	Radius	100	2	1.2%	102	4	2.3%	202	6	3.0%
	Subtotal	296	7	2.4%	300	10	3.3%	596	17	2.9%
Lower limbs	Femur	99	8	4.8%	99	5	3.0%	198	13	3.9%
	Patella	90	1	0.6%	88	1	0.6%	178	2	0.6%
	Tibia	98	8	4.8%	100	12	7.1%	198	20	5.9%
	Calcaneus	99	1	0.6%	100	5	3.0%	199	6	1.8%
	Subtotal	386	18	4.7%	387	23	5.9%	773	41	5.3%
Total		682	25	3.7%	687	33	4.8%	1369	61	4.5%

The percentages observed in the "hard tissue" and the "soft tissue" (Table 3-58) categories were consistent with those observed in the overall percentages particularly in the femur, which is the only bone showing higher frequencies in the soft tissue category (4.5%) than the hard tissue category (2%). This trend was also reflected in the subtotal percentages of the lower limbs, where both categories indicated similar values.

Table 3-58. Frequencies of the traumatic injuries by pooled categories of soft tissue and hard tissue. NILMFS skeletal collection.

Anatomical region	Bone	N	Hard tissue f	Hard tissue %	Soft tissue f	Soft tissue %
Upper limbs	Humerus	201	3	1.5%	2	1.0%
	Radius	193	6	3.1%	0	0.0%
	Ulna	202	4	2.0%	2	1.0%
	Subtotal	596	13	2.2%	4	0.7%
Lower limbs	Femur	198	4	2.0%	9	4.5%
	Patella	178	2	1.1%	0	0.0%
	Tibia	198	11	5.6%	9	4.5%
	Calcaneus	199	4	2.0%	2	1.0%
	Subtotal	773	21	2.7%	20	2.6%
Overall	Total	1369	34	2.5%	24	1.8%

The distribution of traumatic injuries by individuals of the three age groups (*mean*=47%, *SD*=3.1%) ranged from 43.8% to 50% and showed similar trends as the overall sample, in which the middle age group evidenced the highest percentage of all (Table 3-59). Chi-squared results showed no association between the presence of traumatic injuries and the age group, X^2 (2, N=102) =0.259, *p=.878*. The same trends were observed in the frequencies of traumatic injuries by bone within the three age groups (Table 3-60), with no association between age group and presence of traumatic injuries on either the right, the left side or the total sample.

Table 3-59. Distribution of the presence of trauma in individuals by age groups, NILMFS skeletal collection

Age range	N	f	%
Young adult	36	17	47.2%
Middle adult	34	17	50.0%
Old adult	32	14	43.8%
Total	102	48	47.1%

Table 3-60. Frequencies of traumatic injuries by bone within the age groups. NILMFS skeletal collection.

	Young adult			Middle adult			Old adult			Total			Chi-squared test		
Side	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**Value**	**df**	**p**
Left	242	10	4.1%	222	9	4.1%	218	6	2.8%	682	25	3.7%	0.759	2	0.684
Right	243	10	4.1%	225	13	5.8%	219	10	4.6%	687	33	4.8%	0.746	2	0.689
Total	485	20	4.1%	447	22	4.9%	437	16	3.7%	1369	58	4.2%	0.889	2	0.641

3.3.1.3. *Comparison of traumatic injuries between collections*

Overall presence of traumatic injuries in each limb by age groups showed that trends were different in each limb and each collection (Table 3-61). Four out of eight values evidenced that the highest frequencies of traumatic injuries were observed in the middle adult group, i.e., the left upper limb and the right lower limbs of the NILMFS skeletal collection, and the right upper limb and the right lower limb of the UdeA skeletal collection. The former three limbs also showed that the young adult group had the second most frequent injuries. The old adult group had the highest frequencies in two limbs, the right upper limb of the NILMFS collection and the left lower limb of the UdeA collection. Only the left lower limb of the NILMFS collection showed that the younger individuals had the most injuries of all. Chi squared test showed that there was no difference in the presence of antemortem trauma within the three age groups in the left or the right side, nor in the upper or the lower limbs.

Table 3-61. Frequencies and Chi squared test of presence of antemortem trauma by limb, side, and age ranges.

		Upper limbs						**Lower limbs**					
			Left			**Right**			**Left**			**Right**	
Collection	**age range**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**	**N**	**f**	**%**
NILMFS	Young adult	36	4	11%	36	2	6%	35	8	23%	35	8	23%
	Middle adult	34	4	12%	34	5	15%	32	7	22%	33	10	30%
	Old adult	31	1	3%	32	5	16%	32	5	16%	32	7	22%
	Total	101	9	9%	102	12	12%	99	20	20%	100	25	25%
Chi square	X^2		1.79			2.08			0.624			0.747	
	df		2			2			2			2	
	p -value		0.409			0.353			0.732			0.688	
UdeA	Young adult	35	4	11%	35	5	14%	35	8	23%	35	4	11%
	Middle adult	19	2	11%	19	4	21%	19	3	16%	19	4	21%
	Old adult	15	0	0%	15	2	13%	15	5	33%	15	2	13%
	Total	69	6	9%	69	11	16%	69	16	23%	69	10	14%
Chi square	X^2		1.838			0.518			1.453			0.941	
	df		2			2			2			2	
	p -value		0.399			0.772			0.484			0.625	
Total	Young adult	71	8	11%	71	7	10%	70	16	23%	70	12	17%
	Middle adult	53	6	11%	53	9	17%	51	10	20%	52	14	27%
	Old adult	46	1	2%	47	7	15%	47	10	21%	47	9	19%
	Total	170	15	9%	171	23	13%	168	36	21%	169	35	21%
Chi square	X^2		3.466			1.438			0.186			1.835	
	df		2			2			2			2	
	p -value		0.177			0.487			0.911			0.400	

3.3.2. Comparison between individuals with trauma and without trauma

3.3.2.1. *Upper limbs*

3.3.2.1.1. General trends of entheseal changes

Overall frequencies of EC in the entheses and joint complexes of 35 individuals exhibiting skeletal evidence of antemortem trauma in the upper limbs (see Chapter 2), were compared to the frequencies of 136 individuals without skeletal evidence of antemortem trauma. All entheses indicated that the individuals without evidence of trauma have higher frequencies of EC than those with skeletal evidence of trauma, however the differences were not significant (Table 3-62). The skeletal evidence of trauma was pooled into left-side and right-side trauma, and the effect of those variables was tested using a GLM model without interactions. The age factor was considered. The results showed that traumatic injuries by side have no significant effects on the overall presence of EC in the left or right upper limb entheses. Age was a significant factor for all entheses in both the left and the right upper limbs, but it ceased to be significant in the left *triceps brachii* after the Bonferroni correction.

Table 3-62. Fisher's exact test, and GLM model comparing EC presence in individuals with trauma and individuals without trauma in the entheses in the upper limb by side and age.

			Subscapularis	**Supraspinatus**	**Infraspinatus**	**Common extensor**	**Common flexor**	**Biceps brachii**	**Triceps brachii**
Left	EC presence	Trauma	23	15	13	17	9	33	26
		%	13%	9%	8%	10%	5%	19%	15%
		Non-trauma	80	44	51	64	45	122	81
		%	47%	26%	30%	37%	26%	71%	47%
		N	171	171	171	171	171	171	171
		Fisher's Exact test	0.562	0.319	1.000	1.000	0.541	0.53	0.121
	GLM without interactions	AICC	36.325	41.361	50.670	37.559	39.446	-	43.371
		Left-side trauma	0.512	0.051	0.795	0.793	0.659	-	0.080
		Right-side trauma	0.551	0.547	0.878	0.826	0.217	-	0.905
		Age range	**0.000**	**0.000**	**0.009**	**0.000**	**0.000**	-	**0.019**
Right	EC presence	Trauma	28	12	13	14	11	33	25
		%	16%	7%	8%	8%	6%	19%	15%
		Non-trauma	86	53	49	66	51	122	81
		%	50%	31%	29%	39%	30%	71%	47%
		N	171	171	171	171	171	171	171
		Fisher's Exact test	0.071	0.698	1.000	0.448	0.559	0.53	0.55
	GLM without interactions	AICC	39.471	45.929	40.306	-	39.214	-	-
		Left-side trauma	0.063	0.646	0.717	-	0.588	-	-
		Right-side trauma	0.450	0.698	0.666	-	0.552	-	-
		Age range	**0.000**	**0.000**	**0.000**	-	**0.001**	-	-

Bold numbers indicate significance at 0.05 level.

The joint complexes of the upper limbs showed the same trends as the entheses, in which the individuals without skeletal evidence of trauma had a higher presence of EC than the individuals with trauma, but the results do not reach statistical significance in any of the three joint complexes of the upper limbs (Table 3-63). The GLM model without interaction showed that the left-side trauma and the right-side trauma had no significant effect on the overall presence of EC. Age was a significant factor for EC presence in the joint complexes of the upper limbs that could be tested.

Table 3-63. Fisher's exact test, and GLM model comparing EC presence in individuals with trauma and individuals without trauma in the joint complexes in the upper limbs.

		Left			**Right**		
		Shoulder	**Elbow**	**Wrist/ hand**	**Shoulder**	**Elbow**	**Wrist/ hand**
EC presence	Trauma	26	34	20	29	35	19
	%	15%	20%	12%	17%	20%	11%
	Non-trauma	93	128	74	103	126	75
	%	54%	75%	43%	60%	74%	44%
	N	171	171	171	171	171	171
	Fisher's Exact test	0.544	0.688	0.850	0.499	0.217	1.000
GLM without interactions	AICC	-	-	37.235	33.354	-	40.267
	Left-side trauma	-	-	0.914	0.076	-	0.851
	Right-side trauma	-	-	0.853	0.587	-	0.426
	Age range	-	-	**0.000**	**0.001**	-	**0.000**

Bold numbers indicate significance at 0.05 level.

All the above tests evidenced that the proportions of EC present in the entheses of the upper limbs of individuals exhibiting trauma are not significantly different from the EC present in individuals without trauma

3.3.2.1.2. Analysis by features

The effect of trauma in the EC was further explored by feature (Table 3-64). The Fisher's exact test was significant for 13 out of the 106 cases tested (12.3%). Except for bone formation in both zones of the *biceps brachii* insertion, the other 11 significant cases have a positive association between EC and antemortem trauma. Although each feature showed a different trend depending on the enthesis analyzed, most of them were asymmetrical when the traumatic injury was reported in the opposite side or other section of the same limb. Only the textural change in the left *subscapularis* and macro-porosity in the left common extensor were observed in the same joint as the traumatic lesion. Fine porosity in the right *subscapularis* and erosion (Z1) in the right *supraspinatus* evidenced significant relationships with traumatic injuries in the right side, however neither had significant relationships with antemortem trauma in the same joint complex i.e., shoulder. The right *subscapularis* showed that fine porosity was associated with trauma in the left side. The same was true for erosion (Z1) on the right *supraspinatus* when injuries were seen in the left elbow and left wrist/hand. Except for the last two cases that had Cramer's V values <0.5, all the other associations had Cramer's V values <0.3.

The effect of trauma was also tested within each one of the features of the joint complexes in the upper limbs (Table 3-65). The results of Fisher's exact tests showed that four out of forty-eight cases (8.3%) had significant differences in the presence of EC between the individuals with traumatic injuries and those without traumatic injuries. The trends observed were the same as the trends of the features by enthesis, in which the presence of EC was significantly higher on the opposite side to the lesion or different joints than those with which the lesion is associated. However, all the effect size were small. The four features showing differences were: fine porosity in the left shoulder when injuries were seen in the same arm, mostly when the injuries were in the left forearm. Textural change and fine porosity in the right shoulder were present when the left shoulder was injured or overall injuries, respectively, were found. Presence of erosion (Z2) was seen in the left elbow when the right arm was injured, particularly in the forearm.

In conclusion, the individuals with presence of traumatic injuries had significantly higher proportions of EC presence in the upper limb entheses located on the same side as the lesion, as well as the opposite side, but almost all associations had Cramer's V values <0.3.

Table 3-64. Fisher's exact test comparing presence of EC between individuals with and without antemortem trauma by feature in the entheses of the upper limbs.

					presence of trauma					
				Joint	Upper limbs		Left side		Right side	
Enthesis	**Side**	**Feature**	**N**	**complex**	**Fisher's**	**Phi**	**Fisher's**	**Phi**	**Fisher's**	**Phi**
Subscapularis	Left	ER(Z1)	161	Overall	0.262	0.1	0.704	0.04	0.094	0.15
				Shoulder			1.000	0.01	0.381	0.09
				Elbow			1.000	0.01	**0.025**	**0.19**
				Wrist/hand			1.000	0.01	**0.034**	**0.18**
		TC	165	Overall	0.362	0.07	0.217	0.09	1.000	0.03
				Shoulder			**0.037**	**0.20**	0.640	0.04
				Elbow			1.000	-0.03	1.000	-0.00
				Wrist/hand			1.000	-0.03	1.000	-0.00
		FPO	166	Overall	0.108	0.13	0.052	0.17	0.254	0.1
				Shoulder			1.000	0.07	1.000	-0.03
				Elbow			**0.024**	**0.21**	0.091	0.14
				Wrist/hand			**0.024**	**0.21**	0.107	0.13
	Right	TC	166	Overall	0.701	0.04	0.075	0.16	0.369	0.11
				Shoulder			**0.015**	**0.26**	0.601	0.08
				Elbow			0.234	0.09	0.611	-0.09
				Wrist/hand			0.234	0.09	0.617	-0.1
		FPO	166	Overall	**0.018**	**0.2**	**0.001**	**0.32***	**0.045**	**0.17**
				Shoulder			0.155	0.13	0.619	0.1
				Elbow			**0.025**	**0.21**	**0.013**	**0.23**
				Wrist/hand			**0.025**	**0.21**	**0.016**	**0.22**
Supraspinatus	Right	ER(Z1)	150	Overall	**0.031**	**0.22**	**0.005**	**0.33***	0.086	0.18
				Shoulder			0.221	0.13	1.000	-0.04
				Elbow			**0.002**	**0.37***	0.057	0.21
				Wrist/hand			**0.002**	**0.37***	0.064	0.2
CEO	Left	MPO	146	Overall	0.177	0.13	**0.046**	**0.23**	0.449	0.06
				Shoulder			1.000	0.04	1.000	0.05
				Elbow			**0.029**	**0.27**	0.375	0.08
				Wrist/hand			**0.029**	**0.27**	0.394	0.07
CFO	Right	TC	138	Overall	0.183	0.13	1.000	-0.06	0.091	0.18
				Shoulder			1.000	0.04	**0.032**	**0.27**
				Elbow			1.000	0.05	0.066	0.21
				Wrist/hand			1.000	0.05	0.074	0.20
Biceps brachii	Left	BF(Z1)	160	Overall	0.287	0.09	**0.037**	**-0.18**	1.000	0.02
				Shoulder			0.121	-0.15	0.353	0.1
				Elbow			0.298	0.1	0.783	0.04
				Wrist/hand			0.298	0.1	0.790	0.02
		BF(Z2)	161	Overall	0.515	-0.06	0.535	0.06	0.446	-0.09
				Shoulder			0.681	0.07	**0.04**	**-0.17**
				Elbow			0.184	0.11	0.783	-0.04
				Wrist/hand			0.184	0.11	0.784	-0.05
		FPO	161	Overall	**0.037**	**0.19**	0.130	0.14	**0.016**	**0.2**
				Shoulder			1.000	0.05	0.115	0.15
				Elbow			0.101	0.16	**0.031**	**0.21**
				Wrist/hand			0.101	0.16	**0.036**	**0.21**
	Right	ER(Z2)	165	Overall	0.126	0.12	1.000	0.01	**0.033**	**0.18**
				Shoulder			0.681	0.06	**0.044**	**0.18**
				Elbow			0.518	0.05	0.407	0.06
				Wrist/hand			0.518	0.05	0.267	0.09
Triceps brachii	Left	ER(Z2)	146	Overall	0.213	0.11	0.747	0.03	0.127	0.15
				Shoulder			0.678	0.02	0.443	0.06
				Elbow			0.475	0.07	**0.045**	**0.19**
				Wrist/hand			0.475	0.07	0.053	0.18

*Bold numbers indicate significance at 0.05 level. * indicate medium effect size. BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity.*

Table 3-65. Fisher's exact test comparing presence of EC between individuals with and without antemortem trauma by feature in the joint complexes of the upper limbs.

Joint complex	Side	Feature	N	presence of trauma						
				Joint complex	**Upper limbs**		**Left side**		**Right side**	
					Fisher's	**Phi**	**Fisher's**	**Phi**	**Fisher's**	**Phi**
Shoulder	Left	FPO	171	Overall	0.106	0.13	**0.007**	**0.23**	0.595	0.04
				Shoulder			0.367	0.09	0.737	-0.05
				Elbow			**0.032**	**0.18**	0.240	0.09
				Wrist/hand			**0.032**	**0.18**	0.379	0.08
	Right	TC	171	Overall	1.000	0.01	0.515	0.05	0.576	-0.07
				Shoulder			**0.046**	**0.17**	0.735	0.02
				Elbow			1.000	-0.03	1.000	-0.03
				Wrist/hand			1.000	-0.03	0.768	-0.04
		ER(Z1)	171	Overall	0.252	0.09	0.406	0.07	0.165	0.12
				Shoulder			1.000	0.01	0.670	0.02
				Elbow			0.182	0.1	0.051	0.16
				Wrist/hand			0.182	0.1	0.063	0.05
		FPO	171	Overall	0.220	0.1	**0.012**	**0.21**	0.391	0.07
				Shoulder			0.637	0.04	0.470	0.09
				Elbow			0.062	0.15	0.119	0.12
				Wrist/hand			0.062	0.15	0.211	0.11
Elbow	Left	ER(Z2)	171	Overall	0.075	0.14	0.791	0.02	**0.040**	**0.16**
				Shoulder			1.000	0.01	0.084	0.14
				Elbow			0.383	0.07	**0.040**	**0.17**
				Wrist/hand			0.383	0.07	**0.023**	**0.19**

Bold numbers indicate significance at 0.05 level. ER(Z1)= erosion in zone 1, TC= textural change, ER(Z2)= erosion in zone 2, FPO= fine porosity.

3.3.2.1.3. Age ranges

When the age factor is included in the comparison, the differences of EC presence between individuals exhibiting trauma in the upper limbs and those without trauma are stronger than the general trends and the EC are focused on the rotator cuff entheses (Table 3-66). The young adults evidenced that injuries are associated with EC in the right *subscapularis*, while EC in the middle adults are mostly seen in the right *supraspinatus*. Old adults had erosions in the left *infraspinatus* and the right *biceps brachii*. However, only the presence of fine porosity in the right *subscapularis* of the young individuals when the left arm was injured remained significant after the Bonferroni correction.

Table 3-66. Fisher's exact test and phi showing association between EC and antemortem trauma when age is controlled for.

						Presence of antemortem trauma					
						Upper limbs		**Left side**		**Right side**	
Enthesis	**Side**	**Feature**	**N**	**Age range**	**Joint complex**	**Fisher's**	**Phi**	**Fisher's**	**Phi**	**Fisher's**	**Phi**
Subscapularis	Left	ER(Z2)	171	36-50	Overall	**0.019**	**0.35**	0.101	0.26	**0.014**	**0.39**
					Shoulder			0.518	0.07	0.057	0.31
					Elbow			0.101	0.26	0.051	0.30
					Wrist/hand			0.101	0.26	**0.014**	**0.39**
	Right	BF(Z2)	171	20-35	Overall	0.167	0.17	0.230	0.15	**0.030**	**0.33**
					Shoulder			1.000	-0.10	0.313	0.15
					Elbow			0.099	0.25	**0.018**	**0.37**
					Wrist/hand			0.099	0.25	**0.018**	**0.37**
		FPO	171	20-35	Overall	**0.043**	**0.29**	**0.010***	**0.42**	0.424	0.09
					Shoulder			**0.039**	**0.35**	1.000	-0.06
					Elbow			0.322	0.14	0.375	0.11
					Wrist/hand			0.322	0.14	0.375	0.11
Supraspinatus	Left	TC	171	20-35	Overall	0.305	0.12	1.000	-0.11	0.091	0.27
					Shoulder			1.000	-0.09	**0.021**	**0.44**
					Elbow			1.000	-0.08	0.394	0.11
					Wrist/hand			1.000	-0.08	0.394	0.11
		FPO	171	36-50	Overall	0.323	0.20	0.157	0.24	0.071	0.30
					Shoulder			1.000	-0.10	0.503	0.08
					Elbow			0.157	0.24	**0.050**	**0.34**
					Wrist/hand			0.157	0.24	0.071	0.30
	Right	ER(Z1)	171	36-50	Overall	0.053	0.38	**0.014**	**0.55**	**0.020**	**0.50**
					Shoulder			1.000	-0.06	1.000	-0.06
					Elbow			**0.014**	**0.55**	**0.014**	**0.55**
					Wrist/hand			**0.014**	**0.55**	**0.020**	**0.50**
		FPO	171	36-50	Overall	0.253	0.15	0.107	0.25	1.000	-0.10
					Shoulder			**0.042**	**0.35**	1.000	-0.06
					Elbow			1.000	-0.08	1.000	-0.09
					Wrist/hand			1.000	-0.08	1.000	-0.09
Infraspinatus	Left	ER(Z2)	171	51-65	Overall	**0.025**	**0.39**	0.433	0.14	**0.013**	**0.44**
					Shoulder			-	-	**0.024**	**0.41**
					Elbow			0.433	0.14	0.083	0.31
					Wrist/hand			0.433	0.14	0.083	0.31
	Right	FPO	171	20-35	Overall	0.252	0.15	0.124	0.24	1.000	-0.10
					Shoulder			**0.049**	**0.35**	1.000	-0.06
					Elbow			1.000	-0.09	1.000	-0.10
					Wrist/hand			1.000	-0.09	1.000	-0.10
Biceps brachii	Left	BF(Z2)	171	51-65	Overall	**0.035**	**-0.4**	1.000	-0.12	**0.035**	**-0.36**
					Shoulder			-	-	0.073	-0.30
					Elbow			1.000	-0.12	0.142	-0.27
					Wrist/hand			1.000	-0.12	0.142	-0.27
	Right	ER(Z2)	171	51-65	Overall	0.126	0.27	1.000	0.04	**0.045**	**0.33**
					Shoulder			-	-	**0.031**	**0.35**
					Elbow			1.000	0.04	0.375	0.14
					Wrist/hand			1.000	0.04	0.375	0.14

*Bold numbers indicate significance at 0.05 level. * Indicates significant values after the Bonferroni correction. ER(Z1)= erosion zone 1, TC= textural change, BF(Z2)= bone formation zone 2, ER(Z2)= erosion zone 2, FPO= fine porosity.*

3.3.2.1.4. Asymmetry

The asymmetry trends of EC presence in the entheses in the upper limb of the 35 individuals with skeletal evidence of traumatic injuries were compared to the asymmetry trends of the 136 individuals without skeletal evidence of traumatic injuries (Table 3-67). The proportions by enthesis indicated that most asymmetries were observed in the individuals without trauma. Except for the left-side asymmetry of the *subscapularis*, the right-side asymmetry of the *supraspinatus* and the common extensor; and both the left-side and the right-side asymmetry of the *biceps brachii* insertion that showed higher proportions in individuals with trauma. However, the Chi squared test evidenced that none of the differences between the individuals with and without traumatic injuries were statistically significant. The GLM models without interactions evidenced that neither the left-side trauma nor the right-side trauma affected the presence of EC in any of the upper limb entheses.

The proportions by joint complexes showed that the individuals without traumatic injuries had more asymmetry in the shoulders, elbows, and the left hand than those without traumatic injuries (Table 3-68). Yet, the results of the Chi squared test indicated that none of the differences in the proportions of EC present were significant. The GLM model without interactions evidenced that neither the left-side trauma nor the right-side trauma affected the asymmetry trends of the joint complexes in the upper limbs.

The results evidenced that the overall asymmetry trends of the entheses of the upper limbs of individuals with traumatic injuries are not different from the EC trends of the individuals without traumatic injuries.

Table 3-67. Frequencies, Chi squared test, Cramer's V and GLM model comparing asymmetry in individuals with trauma and individuals without trauma in the entheses of the upper limb.

		Subscapularis				Supraspinatus				Infraspinatus				Common extensor				Common flexor				Biceps brachii				Triceps brachii			
		Trauma		no trauma		Trauma		no trauma		Trauma		no trauma		Trauma		no trauma		Trauma		no trauma		Trauma		no trauma		Trauma		no trauma	
		f	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%
Asymmetry	Left-side higher	7	20.0	22	16.2	3	8.6	19	14.0	4	11.4	23	16.9	4	11.4	22	16.2	5	14.3	21	15.4	2	5.7	7	5.1	3	8.6	27	19.9
	Equal	26	74.3	98	72.1	26	74.3	107	78.7	27	77.1	88	64.7	24	68.6	94	69.1	27	77.1	100	73.5	31	88.6	122	89.7	28	80.0	89	65.4
	Right-side higher	2	5.7	16	11.8	6	17.1	10	7.4	4	11.4	25	18.4	7	20.0	20	14.7	3	8.6	15	11.0	2	5.7	7	5.1	4	11.4	20	14.7
	N	171				171				171				171				171				171				171			
	Chi-square test	1.23				3.21*				1.96				0.91				0.23				0.037*				3.10			
	df	2				2				2				2				2				2				2			
	p-value	0.541				0.201				0.375				0.635				0.89				0.981				0.213			
GLM without interactions	AICC	31.313				31.466				35.486				37.957				29.744				26.566				38.074			
	Left-side trauma	0.141				0.107				0.72				0.811				0.952				0.445				0.24			
	Right-side trauma	0.888				0.359				0.786				0.462				0.709				0.266				0.783			

** Indicates that assumptions of Pearson Chi squared test were violated, and Likelihood-Ratio test was used instead.*

Table 3-68. Frequencies, Chi squared test, Cramer's V and GLM model comparing asymmetry in individuals with trauma and individuals without trauma in the joint complexes of the upper limb.

		Shoulder				**Elbow**				**Wrist/ hand**			
		Trauma		non-trauma		Trauma		non-trauma		Trauma		non-trauma	
		f	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%
Asymmetry	Left-side higher	5	14.3	24	17.6	1	2.9	5	3.7	6	17.1	25	18.4
	Equal	28	80.0	98	72.1	34	97.1	124	91.2	22	62.9	87	64.0
	Right-side higher	2	5.7	14	10.3	0	0.0	7	5.1	7	20.0	24	17.6
	N	171				171				171			
	Chi-square test	1.05				3.37*				0.11			
	df	2				2				2			
	p-value	0.592				0.186				0.945			
GLM without interactions	AICC	29.616				22.026				34.955			
	Left-side trauma	0.232				0.199				0.942			
	Right-side trauma	0.566				0.907				0.705			

** Indicates that assumptions of Pearson Chi squared test were violated, and Likelihood-Ratio test was used instead.*

3.3.2.2. *Lower limbs*

3.3.2.2.1. General trends of EC presence

The comparison of the overall frequencies of EC presence in the lower limbs between the 61 individuals with trauma and 110 individuals without trauma evidenced the same trends as the upper limbs, in which the traumatic injuries were not related to the overall presence of EC in any of the entheses, but none of the results were significant (Table 3-69). The GLM model without interactions showed that neither the traumatic injuries in the left-side nor the right-side had an impact on the overall presence of EC in the entheses in the lower limbs. Age has an effect on the iliopsoas and the three entheses located below the knee.

Table 3-69. Fisher's exact test, and GLM model comparing EC presence in individuals with trauma and individuals without trauma in the entheses of the lower limb by side. Age was used as a predictor.

Side			**Iliopsoas**	**Gastrocnemius**	**Quadriceps femoris**	**Vastus lateralis**	**Patella ligament**	**Triceps surae**	**Plantar fascia**
Left	EC presence	Trauma	45	35	33	42	43	49	20
		%	26%	20%	19%	25%	25%	29%	12%
		Non-trauma	79	64	58	76	70	89	42
		%	46%	37%	34%	44%	41%	52%	25%
		N	171	171	171	171	171	171	171
		Fisher's Exact test	0.859	1.000	0.874	1.000	0.403	1.000	0.511
	GLM without interactions	AICC	41.856	44.812	51.144	43.262	45.583	39.398	48.571
		Left-side trauma	0.187	0.380	0.122	0.702	0.150	0.907	0.463
		Right-side trauma	0.633	0.358	0.229	0.712	0.845	0.620	0.932
		Age range	**0.034**	0.223	0.889	0.422	**0.000***	**0.006***	**0.018**
Right	EC presence	Trauma	38	28	43	48	37	51	25
		%	22%	16%	25%	28%	22%	30%	15%
		Non-trauma	68	46	68	74	70	91	44
		%	40%	27%	40%	43%	41%	53%	26%
		N	171	171	171	171	171	171	171
		Fisher's Exact test	1.000	0.632	0.316	0.157	0.743	1.000	1.000
	GLM without interactions	AICC	45.076	49.532	49.79	46.833	46.402	37.317	46.922
		Left-side trauma	0.576	0.537	0.285	0.403	0.601	0.072	0.884
		Right-side trauma	0.685	0.554	0.786	0.23	0.92	0.122	0.689
		Age range	**0.000***	**0.028**	0.08	0.927	**0.000***	**0.002***	**0.000***

*Bold numbers indicate significance at 0.05 level. * Indicates significance after the Bonferroni correction.*

The comparison of EC presence by the joint complexes indicated that individuals with traumatic injuries had lower frequencies of EC presence in the knee and the ankle/foot joint complex than the individuals without traumatic injuries (Table 3-70), however none of these two trends were significant. The GLM model without interactions showed that none of the factors considered affect the presence of EC in the joint complexes of the lower limbs.

Table 3-70. Fisher's exact test, and GLM model comparing EC presence in individuals with trauma and individuals without trauma in the joint complexes of the lower limb.

Side			**Knee**	**ankle/foot**
Left	EC presence	Trauma	48	47
		%	33%	31%
		Non-trauma	84	88
		%	58%	59%
		N	146	150
		Fisher's Exact test	0.380	0.778
	GLM without interactions	AICC	31.44	30.487
		Left-side trauma	0.595	0.773
		Right-side trauma	0.569	0.296
		Age range	0.322	0.068
Right	EC presence	Trauma	43	51
		%	28%	33%
		Non-trauma	90	90
		%	59%	58%
		N	152	156
		Fisher's Exact test	0.795	0.577
	GLM without interactions	AICC	37.501	-
		Left-side trauma	0.208	-
		Right-side trauma	0.816	-
		Age range	0.134	-

The results obtained for the overall trends of the lower limbs indicated that the proportions of EC present in the entheses of individuals exhibiting trauma are not significantly different from the EC present in individuals without trauma.

3.3.2.2.2. Analysis by features

Differences between individuals with and without traumatic injuries in the lower limbs were further analyzed by feature (Table 3-71). The general trend of the features showing statistical significance evidenced that entheseal changes, particularly fine porosity, were more frequent in the same side and the same joint as the antemortem lesion. Only the *triceps surae* enthesis showed that bone formation in both zones was more frequent in the opposite side of the lesion than the same side. Textural change showed significant results in five entheses, of which only the *quadriceps femoris* and the *triceps surae* in the left side evidenced higher frequency in individuals exhibiting traumatic injuries compared to individuals without them. While the iliopsoas, gastrocnemius and *quadriceps femoris* entheses in the right side had significantly less presence of textural change when antemortem trauma was present.

Fisher's exact test evidenced that the differences between the two groups were significant in fifteen out of eighty-six features (17.4%), of which the relationship between traumatic injuries in the left hip and the presence of fine porosity in the left *quadriceps femoris* had a Cramer's V value <0.5. Fisher's exact test indicated that the presence of textural change in the right *quadriceps femoris* was significantly lower when traumatic injuries were observed in the right knee.

Four out of twenty-eight features (14.3%) of the joint complexes showed association between antemortem trauma and presence of EC (Table 3-72). The significant trends were consistent with those observed in the lower limb entheses, in which all features in the knee had higher frequencies when traumatic injuries were seen in the same limb. Only bone formation (Z1) in the ankle/foot evidenced the opposite trend. The left knee showed that three different features had significant relationship with traumatic injuries, however, the only significant feature seen in the right knee, fine porosity, evidenced the strongest relationship within all features and the only one with a medium effect size. The ankle/foot joint complex showed that only bone formation (Z1) was statistically related to an injury on the opposite side.

The results of Fisher's exact test showed that the effect of trauma in the entheseal changes in the lower limbs were focused on the same side and near to the traumatic injuries. Only two features indicated more presence when traumatic injuries were observed on the opposite side. Therefore, the proportions of EC present in the lower limb entheses of individuals exhibiting traumatic injuries are significantly different from the EC present in individuals without trauma.

Table 3-71. Fisher's exact test and Cramer's V comparing individuals with and without traumatic injuries by feature in the entheses of the lower limbs.

				Presence of antemortem trauma						
				Joint	Lower limbs		Left side		Right side	
Enthesis	**Side**	**Feature**	**N**	**complex**	**Fisher's**	**Phi**	**Fisher's**	**Phi**	**Fisher's**	**Phi**
Iliopsoas	Right	TC	153	Overall	0.864	0.01	0.541	0.06	0.423	0.07
				Hip			0.769	-0.04	1.000	0.01
				Knee			1.000	-0.01	**0.037**	**-0.18**
				Ankle/foot			0.627	0.05	0.811	-0.04
		ER(Z2)	153	Overall	1.000	0.01	**0.013**	**-0.20**	**0.024**	**0.19**
				Hip			**0.021**	**-0.18**	0.103	0.14
				Knee			**0.009**	**-0.21**	0.077	0.15
				Ankle/foot			0.284	-0.11	0.294	0.10
Gastrocnemius	Right	TC	163	Overall	0.234	-0.10	1.000	-0.11	**0.017**	**-0.18**
				Hip			0.736	-0.05	0.305	-0.10
				Knee			1.000	0.01	**0.029**	**-0.17**
				Ankle/foot			1.000	0.00	**0.048**	**-0.16**
		ER(Z2)	163	Overall	0.310	0.09	1.000	0.00	0.069	0.15
				Hip			0.669	0.03	1.000	-0.04
				Knee			1.000	-0.01	0.742	-0.04
				Ankle/foot			1.000	0.01	**0.025**	**0.19**
Quadriceps femoris	Left	TC	149	Overall	0.319	0.08	0.089	0.16	0.639	-0.06
				Hip			**0.022**	**0.20**	0.734	-0.06
				Knee			**0.034**	**0.19**	1.000	-0.03
				Ankle/foot			0.154	0.12	1.000	0.01
		FPO	149	Overall	0.125	0.16	**0.039**	**0.23**	1.000	-0.06
				Hip			**0.008**	**0.36***	1.000	-0.04
				Knee			**0.025**	**0.27**	1.000	-0.05
				Ankle/foot			1.000	-0.05	1.000	-0.05
	Right	TC	142	Overall	1.000	0.01	0.505	0.07	0.187	-0.12
				Hip			0.302	0.10	**0.034**	**-0.19**
				Knee			0.219	0.12	0.082	-0.15
				Ankle/foot			1.000	-0.01	1.000	-0.01
		FPO	142	Overall	0.138	0.16	1.000	-0.06	**0.046**	**0.23**
				Hip			1.000	-0.04	0.149	0.19
				Knee			1.000	-0.05	**0.023**	**0.28**
				Ankle/foot			1.000	-0.05	0.275	0.12
Patella ligament	Left	BF(Z2)	150	Overall	**0.017**	**0.20**	**0.019**	**0.21**	0.315	0.08
				Hip			0.231	0.12	0.294	0.08
				Knee			**0.009**	**0.24**	0.375	0.09
				Ankle/foot			**0.038**	**0.18**	1.000	0.00
		FPO	150	Overall	0.367	0.08	0.137	0.14	0.467	-0.10
				Hip			0.056	0.19	0.605	-0.10
				Knee			**0.036**	**0.19**	0.216	-0.12
				Ankle/foot			0.087	0.15	1.000	-0.05
	Right	BF(Z1)	154	Overall	1.000	0.00	0.843	-0.03	0.550	0.06
				Hip			0.230	-0.12	**0.005**	**0.23**
				Knee			1.000	-0.01	0.646	0.05
				Ankle/foot			1.000	0.02	0.483	-0.06

*Bold numbers indicate significance at 0.05 level. * Indicates medium effect size. BF(Z1)= bone formation in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity.*

continuation Table 3-71. Fisher's exact test and phi comparing individuals with and without traumatic injuries by feature in the entheses of the lower limbs.

				Presence of antemortem trauma						
				Joint	Lower limbs		Left side		Right side	
Enthesis	**Side**	**Feature**	**N**	**complex**	**Fisher's**	**Phi**	**Fisher's**	**Phi**	**Fisher's**	**Phi**
Patella ligament	Right	ER(Z2)	151	Overall	0.737	0.03	1.000	-0.03	0.123	0.13
				Hip			1.000	-0.08	**0.034**	**0.22**
				Knee			0.671	0.03	0.163	0.12
				Ankle/foot			0.631	0.05	1.000	-0.03
		FPO	151	Overall	**0.003**	**0.26**	0.123	0.13	**0.005**	**0.26**
				Hip			0.182	0.12	**0.034**	**0.22**
				Knee			0.062	0.17	**0.040**	**0.19**
				Ankle/foot			0.146	0.12	**0.028**	**0.21**
Triceps surae	Left	TC	155	Overall	0.279	0.10	0.122	0.13	0.607	0.05
				Hip			1.000	-0.02	1.000	-0.03
				Knee			**0.024**	**0.19**	0.772	0.03
				Ankle/foot			0.215	0.11	0.538	0.06
	Right	BF(Z1)	157	Overall	0.395	0.09	**0.027**	**0.18**	0.613	-0.04
				Hip			1.000	0.03	0.275	0.09
				Knee			0.110	0.14	0.256	-0.11
				Ankle/foot			**0.048**	**0.16**	0.762	-0.02

Bold numbers indicate significance at 0.05 level. BF(Z1)= bone formation in zone 1, TC= textural change, ER(Z2)= erosion in zone 2, FPO= fine porosity.

Table 3-72. Fisher's exact test and phi comparing individuals with and without traumatic injuries by feature in the joint complexes of the lower limbs.

				Presence of antemortem trauma						
				Joint	Lower limbs		Left side		Right side	
Joint complex	**Side**	**Feature**	**N**	**complex**	**Fisher's**	**Phi**	**Fisher's**	**Phi**	**Fisher's**	**Phi**
Knee	Left	TC	171	Overall	0.101	0.13	0.567	0.05	**0.050**	**0.16**
				Hip			0.571	0.06	0.135	0.13
				Knee			1.000	0.00	0.124	0.13
				Ankle/foot			0.374	0.07	0.107	0.13
		FPO	171	Overall	0.585	0.05	0.108	0.13	0.198	-0.11
				Hip			**0.029**	**0.20**	0.614	-0.09
				Knee			**0.033**	**0.18**	0.135	-0.14
				Ankle/foot			0.247	0.10	0.699	-0.07
	Right	FPO	171	Overall	**0.001**	**0.27**	0.281	0.08	**0.000**	**0.32***
				Hip			0.256	0.09	**0.007**	**0.27**
				Knee			0.124	0.12	**0.003**	**0.27**
				Ankle/foot			0.379	0.09	**0.012**	**0.23**
Ankle/foot	Right	BF(Z1)	171	Overall	0.431	0.07	**0.017**	**0.19**	0.638	-0.04
				Hip			0.307	0.01	0.293	-0.08
				Knee			0.072	0.15	0.605	-0.03
				Ankle/foot			**0.050**	**0.16**	0.409	-0.06

*Bold indicates significance at 0.05 level. * Indicates medium effect size. BF(Z1)= bone formation in zone 1, TC= textural change, FPO= fine porosity.*

3.3.2.2.3. Age ranges

The GLM of the general trends showed that less entheses are affected by age in the lower limbs than in the upper limbs. However, the analysis by feature showed greater differences in EC presence between individuals with and without trauma when age is considered in the lower limbs (Table 3-73). Most of the antemortem injuries observed in the young individuals were associated with presence of bone formation in the left knee (Figure 3-1). The middle adults evidenced few EC associated with traumatic injuries, and those were mostly seen in the right knee (Figure 3-2). The old adults were the group showing most associations, especially in the right knee and the *triceps surae* of both sides (Figure 3-3). After the Bonferroni correction four comparisons remained statistically significant. All the four differences involved bone formation in the left side, these were presence of bone formation in the *vastus lateralis* and patellar ligament in the left leg of the young adults, presence of bone formation in the left gastrocnemius in the middle adults, and presence of bone formation in the left *triceps surae* of the old adults.

Table 3-73. Fisher's exact test and phi values showing association between EC in the lower limbs and antemortem trauma when age is controlled for.

						Presence of antemortem trauma					
						Lower limbs		**Left side**		**Right side**	
Enthesis	**Side**	**Feature**	**N**	**Age range**	**Joint complex**	**Fisher's**	**Phi**	**Fisher's**	**Phi**	**Fisher's**	**Phi**
Iliopsoas	Right	TC	44	51-65	Overall	1.000	-0.03	0.287	0.18	0.148	-0.25
					Hip			0.570	0.13	0.622	-0.12
					Knee			0.262	0.18	**0.014**	**-0.38**
					Ankle			0.443	0.12	0.370	-0.17
Gastrocnemius	Left	BF(Z2)	48	36-50	Overall	0.349	0.16	**0.039**	**0.36**	1.000	-0.05
					Hip			0.199	0.27	1.000	-0.10
					Knee			**0.010***	**0.49**	1.000	0.01
					Ankle			0.148	0.25	1.000	0.01
	Right	BF(Z1)	66	20-35	Overall	0.276	0.15	0.127	0.23	0.427	0.10
					Hip			**0.037**	**0.37**	1.000	-0.06
					Knee			0.097	0.26	0.361	0.13
					Ankle			1.000	-0.09	0.326	0.14
		TC	49	36-50	Overall	**0.038**	**-0.31**	0.419	-0.15	**0.045**	**-0.31**
					Hip			1.000	-0.14	0.562	-0.16
					Knee			0.325	-0.22	0.172	-0.24
					Ankle			0.330	-0.08	0.098	-0.26
		ER(Z2)	47	51-65	Overall	0.692	0.06	1.000	-0.07	0.155	0.22
					Hip			1.000	-0.11	1.000	-0.13
					Knee			1.000	-0.03	1.000	-0.01
					Ankle			1.000	-0.03	**0.019**	**0.44**

*Bold numbers indicate significance at 0.05 level. * Indicates significance after the Bonferroni correction. BF(Z1)= Bone formation zone 1, TC= textural change, BF(Z2)= bone formation zone 2, ER(Z2)= erosion zone 2.*

Continuation Table 3-73. Fisher's exact test and phi values showing association between EC in the lower limbs and antemortem trauma when age is controlled for.

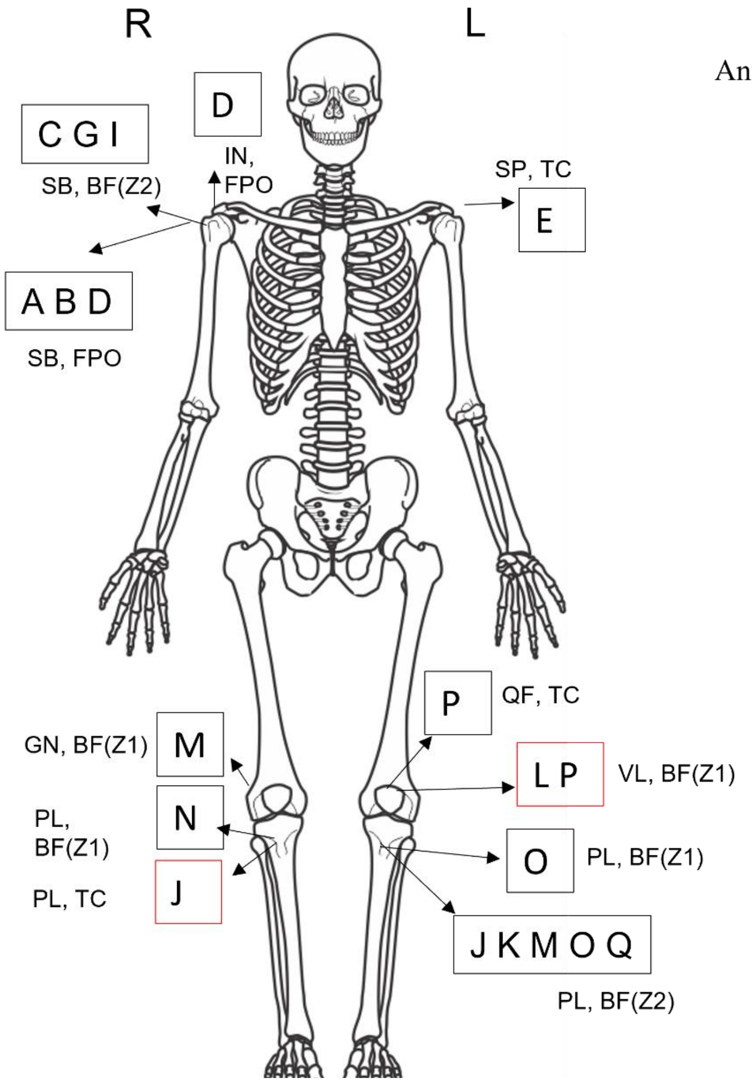
						Presence of antemortem trauma					
						Lower limbs		**Left side**		**Right side**	
Enthesis	**Side**	**Feature**	**N**	**Age range**	**Joint complex**	**Fisher's**	**Phi**	**Fisher's**	**Phi**	**Fisher's**	**Phi**
Quadriceps femoris	Left	TC	62	20-35	Overall	1.000	-0.01	0.315	0.16	0.256	-0.18
					Hip			0.214	0.18	1.000	-0.06
					Knee			0.305	0.14	**0.049**	**-0.26**
					Ankle			0.106	0.24	0.660	-0.12
			45	51-65	Overall	0.131	0.27	0.093	0.27	0.668	0.10
					Hip			0.119	0.29	0.561	-0.17
					Knee			**0.034**	**0.36**	0.172	0.21
					Ankle			0.601	0.11	0.065	0.32
	Right	MPO	40	51-65	Overall	0.375	0.21	0.225	0.30	1.000	-0.08
					Hip			**0.050**	**0.70**	1.000	-0.05
					Knee			0.175	0.35	1.000	-0.06
					Ankle			1.000	-0.07	1.000	-0.05
Vastus lateralis	Left	BF(Z1)	56	20-35	Overall	0.086	-0.24	0.751	-0.07	**0.011***	**-0.33**
					Hip			1.000	0.03	0.652	-0.09
					Knee			1.000	-0.01	**0.021**	**-0.31**
					Ankle			1.000	-0.01	0.082	-0.27
	Right	BF(Z1)	37	51-65	Overall	**0.035**	**0.38**	**0.015**	**0.42**	0.685	0.11
					Hip			0.532	0.18	0.538	0.22
					Knee			**0.038**	**0.36**	1.000	-0.04
					Ankle			**0.038**	**0.36**	0.602	-0.11
Patella ligament	Left	BF(Z1)	65	20-35	Overall	0.417	0.11	0.062	0.25	0.480	-0.14
					Hip			0.672	0.08	1.000	-0.08
					Knee			**0.019**	**0.31**	0.251	-0.18
					Ankle			0.065	0.25	1.000	-0.06
		BF(Z2)	64	20-35	Overall	**0.001**	**0.44**	**0.018**	**0.35**	0.058	0.28
					Hip			**0.014**	**0.40**	0.399	0.11
					Knee			**0.009***	**0.40**	0.196	0.18
					Ankle			**0.032**	**0.33**	0.159	0.20
		BF(Z2)	42	36-50	Overall	**0.021**	**-0.12**	**0.048**	**0.37**	0.328	0.20
					Hip			1.000	-0.07	0.123	0.29
					Knee			0.123	0.29	0.257	0.18
					Ankle			0.188	0.23	1.000	-0.03
	Right	BF(Z1)	61	20-35	Overall	0.257	0.16	1.000	0.03	0.263	0.17
					Hip			1.000	-0.02	**0.014**	**0.35**
					Knee			0.504	0.09	0.240	0.16
					Ankle			0.710	0.07	1.000	-0.02
		TC	61	20-35	Overall	**0.046**	**-0.28**	0.184	-0.22	0.332	-0.17
					Hip			0.579	-0.14	0.481	0.08
					Knee			0.191	-0.20	0.580	-0.15
					Ankle			0.332	-0.17	0.579	-0.14
		FPO	45	36-50	Overall	**0.017**	**0.39**	0.286	0.16	**0.035**	**0.36**
					Hip			0.356	0.16	0.080	0.34
					Knee			0.175	0.23	0.286	0.16
					Ankle			0.125	0.28	0.084	0.29

*Bold numbers indicate significance at 0.05 level. * Indicates significance after the Bonferroni correction. BF(Z1)= Bone formation zone 1, TC= textural change, BF(Z2)= bone formation zone 2, ER(Z2)= erosion zone 2.*

Continuation Table 3-73. Fisher's exact test and phi values showing association between EC in the lower limbs and antemortem trauma when age is controlled for.

					Presence of antemortem trauma						
						Lower limbs		Left side		Right side	
Enthesis	**Side**	**Feature**	**N**	**Age range**	**Joint complex**	**Fisher's**	**Phi**	**Fisher's**	**Phi**	**Fisher's**	**Phi**
Triceps surae	Left	TC	44	51-65	Overall	0.250	0.20	0.068	0.30	0.360	0.16
					Hip			0.101	0.31	1.000	0.04
					Knee			**0.024**	**0.40**	0.619	0.09
					Ankle			0.586	0.13	0.180	0.23
		BF(Z2)	44	51-65	Overall	0.059	0.32	0.716	0.08	**0.008***	**0.42**
					Hip			0.599	0.10	0.335	0.17
					Knee			0.693	0.08	**0.003***	**0.46**
					Ankle			1.000	0.02	**0.044**	**0.33**
		ER(Z2)	44	51-65	Overall	0.543	0.17	0.506	0.09	0.101	0.31
					Hip			0.195	0.29	1.000	-0.09
					Knee			0.413	0.13	0.061	0.38
					Ankle			1.000	-0.11	**0.018**	**0.54**
	Right	TC	44	51-65	Overall	0.080	0.32	**0.037**	**0.36**	0.619	0.09
					Hip			0.061	0.38	1.000	-0.14
					Knee			**0.014**	**0.44**	0.238	0.19
					Ankle			0.307	0.15	0.113	0.30
		ER(Z2)	45	36-50	Overall	0.608	0.09	0.173	0.23	1.000	0.00
					Hip			**0.018**	**0.54**	1.000	-0.10
					Knee			0.108	0.30	1.000	0.04
					Ankle			0.448	0.11	0.505	0.08
		FPO	44	51-65	Overall	0.543	0.17	0.125	0.28	0.101	0.31
					Hip			0.195	0.29	0.254	0.23
					Knee			0.080	0.34	**0.045**	**0.42**
					Ankle			0.413	0.13	0.254	0.23

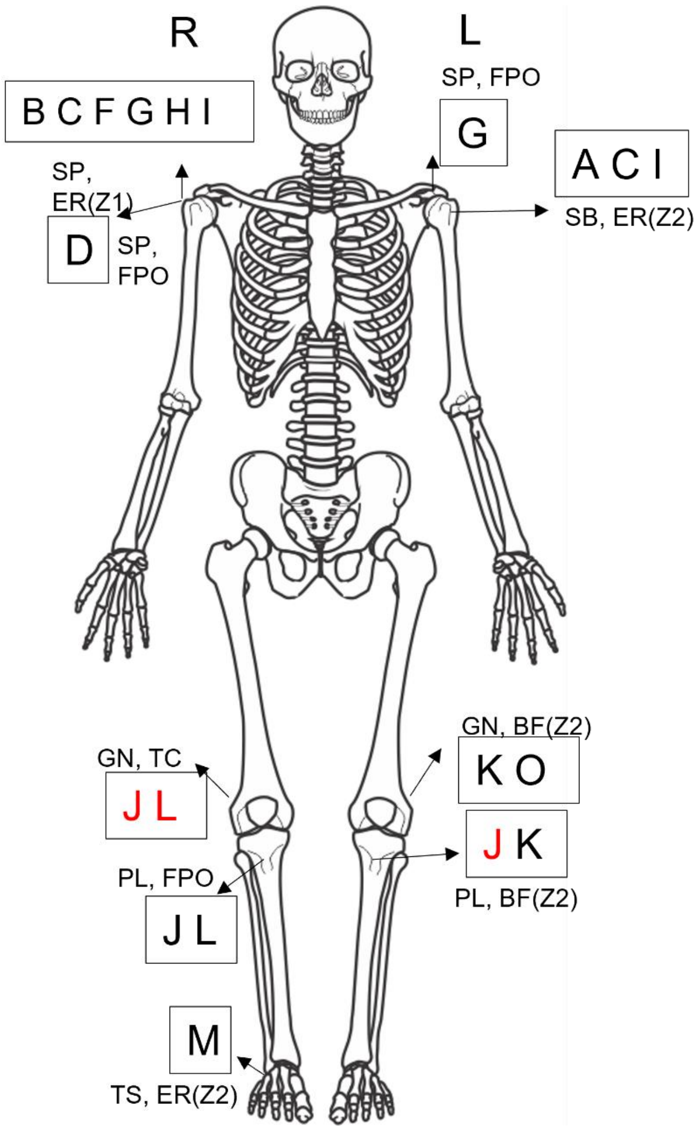
*Bold numbers indicate significance at 0.05 level. * Indicates significance after the Bonferroni correction. BF(Z1)= Bone formation zone 1, TC= textural change, BF(Z2)= bone formation zone 2, ER(Z2)= erosion zone 2.*



Antemortem trauma and EC by age ranges 20-35 years

A	Overall upper limbs
B	Overall left upper limb
C	Overall right upper limb
D	Left shoulder
E	Right shoulder
G	Right elbow
I	Right hand
J	Overall lower limbs
K	Overall left lower limb
L	Overall right lower limb
M	Left hip
N	Right hip
O	Left knee
P	Right knee
Q	Left ankle

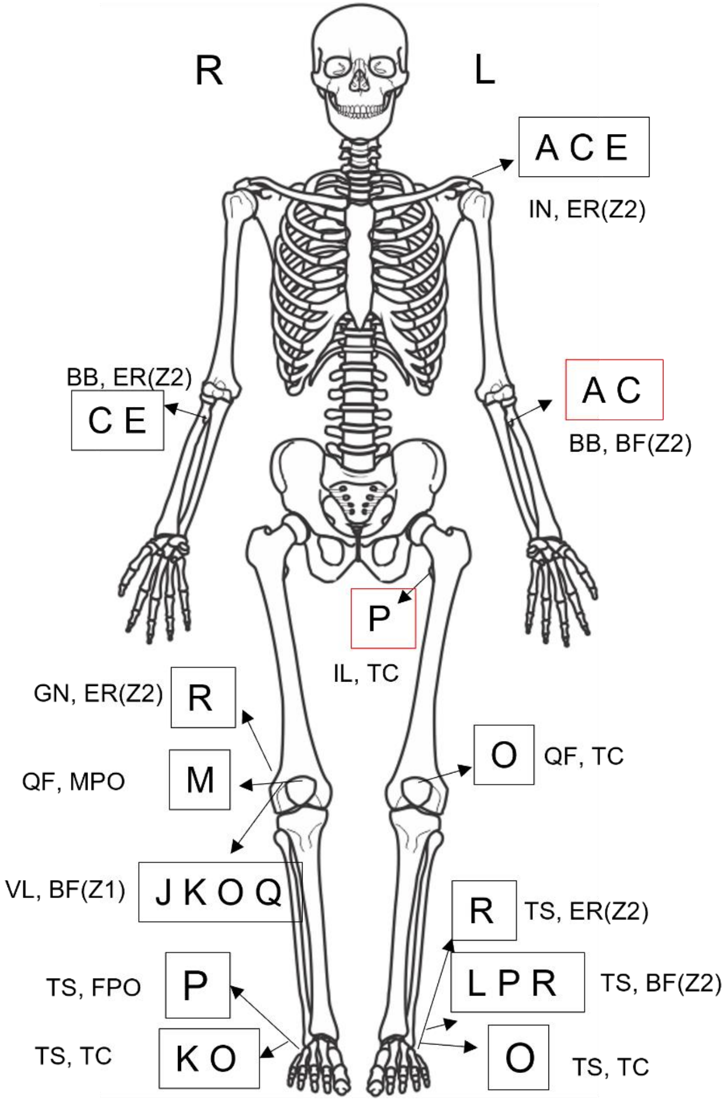
Figure 3-1.Location of EC associated with antemortem trauma in young adults. Red boxes indicated an inverse relationship, i.e., more EC in individuals without trauma.



Antemortem trauma and EC by age ranges 36 – 50 years

A	Overall upper limbs
B	Overall left upper limb
C	Overall right upper limb
D	Left shoulder
F	Left elbow
G	Right elbow
H	Left hand
I	Right hand
J	Overall lower limbs
K	Overall left lower limb
L	Overall right lower limb
M	Left hip
O	Left knee

Figure 3-2. Location of EC associated with antemortem trauma in middle adults. Red numbers indicated an inverse relationship, i.e., more EC in individuals without trauma.



Antemortem trauma and EC
by age ranges 51 – 65 years

A	Overall upper limbs
C	Overall right upper limb
E	Right shoulder
J	Overall lower limbs
K	Overall left lower limb
L	Overall right lower limb
M	Left hip
O	Left knee
P	Right knee
Q	Left ankle
R	Right ankle

Figure 3-3. Location of EC associated with antemortem trauma in old adults. Red boxes indicated an inverse relationship, i.e., more EC in individuals without trauma.

3.3.2.2.4. Asymmetry

The differences in asymmetry proportions between 61 individuals that exhibited traumatic injuries in at least one bone of the lower limbs and 110 individuals without any skeletal signs of traumatic injuries were compared by each of the entheses of the lower limbs (Table 3-74). The frequencies indicated that six out of seven entheses had higher proportions in either left-side or right-side asymmetry when the individuals exhibited traumatic injuries. The iliopsoas and the patellar ligament entheses of individuals with traumatic injuries showed higher asymmetry in the right side compared to the proportions of those without traumatic injuries. While the opposite was seen in the *quadriceps femoris*, *vastus lateralis*, *triceps surae* and plantar fascia entheses which evidenced higher right-side asymmetry in individuals with traumatic injuries. However, the Chi squared test results indicated that the differences between the individuals with and without overall traumatic injuries were not significant.

The GLM models without interaction indicated that neither the left overall trauma nor the right overall trauma had a significant effect on the asymmetry trends of the entheses of the lower limbs, except for patellar ligament enthesis in which the presence of traumatic injuries in the left side affected the asymmetry. This trend was no longer significant after the Bonferroni correction.

The relationship between trauma and EC was also analyzed in the two joint complexes of the lower limbs (Table 3-75). The results indicated that the right-side asymmetry of the knee and both the left-side and the right-side asymmetry of the ankle/foot joint complex were more frequent in individuals with traumatic injuries than those without traumatic injuries. But none of these differences were statistically significant. The GLM models without interaction showed that asymmetry in the joint complexes was no affected by the left overall trauma presence nor the right overall trauma presence.

The results evidenced that the overall asymmetry trends of the entheses of the lower limbs of those individuals with traumatic injuries are not significantly different from the EC trends of the individuals without traumatic injuries.

Table 3-74. Frequencies of EC, Chi squared test, Cramer's V and GLM model comparing asymmetry in individuals with trauma and individuals without trauma in the entheses of the lower limb.

		Iliopsoas				Gastrocnemius				Quadriceps				Vastus lateralis				Patella ligament				Triceps surae				Plantar fascia			
		Trauma		no		Trauma		no		Trauma		no		Trauma		no		Trauma		no		Trauma		no		Trauma		no	
		f	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%
Asymmetry	Left-side higher	6	9.8	11	10.0	5	8.2	11	10.0	14	23.0	22	20.0	13	21.3	14	12.7	4	6.6	11	10.0	7	11.5	11	10.0	11	18.0	15	13.6
	Equal	42	68.9	77	70.0	44	72.1	70	63.6	43	70.5	76	69.1	41	67.2	80	72.7	47	77.0	88	80.0	49	80.3	90	81.8	44	72.1	82	74.5
	Right-side higher	13	21.3	22	20.0	12	19.7	29	26.4	4	6.6	12	10.9	7	11.5	16	14.5	10	16.4	11	10.0	5	8.2	9	8.2	6	9.8	13	11.8
	N	171				171				171				171				171				171				171			
	Chi-square test	0.04				1.29				0.97				2.28				1.88				0.09				0.67			
	df	2				2				2				2				2				2				2			
	p-value	0.979				0.524				0.616				0.321				0.391				0.955				0.716			
GLM without interactions	AICC	35.716				37.583				33.696				36.962				34.114				30.896				35.423			
	Left-side trauma	0.133				0.786				0.541				0.344				**0.028**				0.118				0.637			
	Right-side trauma	0.378				0.646				0.148				0.534				0.79				0.359				0.598			

Bold indicates significance at 0.05 level.

Table 3-75. Frequencies of EC, *Chi squared test, Cramer's V and GLM model comparing asymmetry in individuals with trauma and individuals without trauma in the joint complexes of the lower limb.*

		Knee				**Ankle/foot**			
		Trauma		no trauma		Trauma		no trauma	
		f	%	*f*	%	*f*	%	*f*	%
Asymmetry	Left-side higher	1	2.3	6	6.7	5	10.2	2	2.1
	Equal	39	88.6	76	85.4	41	83.7	88	93.6
	Right-side higher	4	9.1	7	7.9	3	6.1	4	4.3
	N	133				143			
	Likelihood ratio Chi-square test	1.38				4.59			
	df	2				2			
	p-value	0.502				0.101			
GLM without interactions	AICC	28.418				29.39			
	Left-side trauma	0.196				0.232			
	Right-side trauma	0.947				0.626			

3.3.3. Summary of the results

In general, the differences observed between the trends of the two skeletal collections showed that the collection held in Bogota D.C has a higher frequency of ECs than the collection in Medellin. However, the trends change, and the differences are stronger, when the comparison between collections takes age into consideration. The UdeA skeletal collection has a higher frequency of ECs in individuals younger than 50 years, while the NILMFS skeletal collection shows a higher frequency of EC in individuals older than 50 years. The differences in general trends of bilateral asymmetries evidence that the frequency of EC is higher in the NILMFS collection than the UdeA collection. As with the general trends of ECs, the differences in asymmetry between the two collections change and become stronger when the comparison considering the three age ranges is performed.

When comparing presence of ECs in individuals with and without skeletal evidence of antemortem trauma it is evident that textural change, fine porosity, macro-porosity, and erosion are weakly associated with skeletal evidence of antemortem trauma in entheses located in the same limb or opposite limb as the lesion.

4. DISCUSSION

The primary objective of this study was to improve the contribution of forensic anthropology to the personal identification process by analyzing the relationship between entheseal changes and skeletal evidence of antemortem trauma, and the usefulness of their relationship for personal identification in the Colombian context. This research recognizes antemortem trauma only as events that reached the bone tissue (see Chapter 1). Two secondary objectives and the hypotheses aimed to determine whether ECs are affected by population variability, and if there is strong association between skeletal evidence of antemortem trauma and ECs in male Colombian individuals. The entheseal surface of fourteen fibrocartilaginous entheses were assessed in male individuals, aged between 20 and 68 years old, from two identified skeletal collections in Colombia.

As stated in Chapter 1, personal identification in Colombia is challenging due to the large number of pending cases and their complexity, the majority of which are skeletonized bodies (INMLCF, 2020; Sanabria Medina & Osorio Restrepo, 2015). Common problems for identification include lack of access to antemortem records, and difficulty contacting close blood relatives for comparison (Centro Nacional de Memoria Histórica, 2016; Espacio, 2016; López, 2020). In Colombia, as in other conflicts, it is common to find more than one member of the same close blood family within a forensic context, presenting additional identification challenges (Reinoso, 2019; Rodríguez & Arango, 2014; Yazedjian & Kešetović, 2008). These factors limit the effectiveness of DNA, fingerprints, or dental records as means of personal identification, as such strengthening of anthropological identifiers would be highly useful in the Colombian context.

Anthropological identifiers include external morphological features and skeletal features that are particularly relevant when the applicability of traditional methods of personal identification is limited (de Boer et al., 2020). Skeletal features encompass unique characteristics of the bone tissue such as the morphology of skeletal elements, anatomical variants, developmental anomalies, pathological changes, medical interventions, frontal sinus pattern, and trabecular bone pattern that under appropriate field conditions can be used for a conclusive identification. While the external features often used as anthropological identifiers are morphological features on the face, teeth, and skin alterations (de Boer et al., 2020). Attempts to strengthen the methods of forensic anthropology do not run counter to advances in other areas of forensic sciences nor are they intended to replace them, on the contrary, personal identification is an inter-disciplinary process and the strength of one of its parts will be the strength of the whole.

The enthesis is the interface between soft and hard tissue, and as with any other part of the body, it responds to internal and external factors (Benjamin et al., 2002). The normal morphology of the entheseal surface can change in response to factors that affect both soft and hard tissue such as age, BMI, and pathological conditions (Di Matteo et al., 2020). However, each EC appears to have a different response to all factors involved (Villotte et al., 2016), for instance bone formation is the feature most related with aging, while fine porosity is more commonly found in young individuals (Henderson, Mariotti, et al., 2017).

The results of this research found that besides the above factors, some of the entheseal changes appear to be associated with antemortem trauma, i.e., fine porosity, macro/porosity, textural change, and erosion. However, this relationship is not straightforward and other factors such as the individual's physiological limits may play relevant roles. Therefore, further analysis is required to better understand the relationship and be used within the forensic anthropology analysis.

In the twentieth century, entheseal changes were used in a few forensic cases to support inferences about occupation of the skeleton under study (Kennedy, 1983), but given their multifactorial etiology the contribution of EC to forensic identifications quickly ceased (Kennedy, 1998). The anatomical and osteological research of the last three decades have started to untangle the factors involved in the origin of EC, and quantifying the impact of factors on EC presence, e.g., age, sex, biomechanical loads, body size, pathological conditions (Acosta et al., 2017; Benjamin & McGonagle, 2001; Cunha & Umbelino, 1995; Henderson, Mariotti, et al., 2017; Weiss et al., 2012; Wilczak, 1998; Wilczak et al., 2019).

Although age is one of the most important factors, it only explains up to 44% of the variability observed in bone formation and up to 21% of erosions' variability (Henderson, Mariotti, et al., 2017): two of six types of changes most commonly observed in the entheseal surface of the fibrocartilaginous entheses (Henderson et al., 2013, 2016; Villotte et al., 2016). Biomechanical loads are also involved in the presence of entheseal changes (Acosta et al., 2017; Michopoulou, Nikita, et al., 2017; Wilczak et al., 2019), but the methodological difficulty of standardized load levels that allow quantification of the mechanical effect remains one of the main problems (Alves Cardoso & Henderson, 2013). The effect of other potential factors, such as traumatic injuries, are considered to have a possible association with the presence of EC (Schlecht, 2012), but this is the first study of the relationship between EC and skeletal injuries.

These advances in the knowledge of EC origin have revived forensic anthropological research of EC primarily exploring the relationship with aging and BMI (Campanacho, 2016; Godde & Taylor, 2011, 2013). Considering that skeletal features showing antemortem injuries have proven highly valuable for forensic identification (Cunha & Cattaneo, 2018; Djurić, 2004; Ríos et al., 2010) and lesions affecting only the soft tissue are missing from the skeletal evidence, this research focused on establishing whether lesions affect the presence of EC, so that the entheses can give an indication of antemortem lesions.

The discussion of the results focuses on the usefulness of entheseal changes to strengthen forensic anthropology´s contribution to personal identification. The chapter begins with a discussion of the measurement errors of the Coimbra method, followed by biological and socioeconomic differences between Medellín and Bogota D.C., then the general trends of EC presence within each skeletal collection and their association with population variability. The chapter concludes by looking at the effect of antemortem trauma when comparing the trends of EC presence of individuals showing skeletal evidence of traumatic injuries to those individuals without skeletal signs of traumatic injuries. Moreover, the presence of bilateral asymmetry has been suggested to be associated with biomechanical loads that are differentially applied on paired bone structures (Villotte, Castex, et al., 2010; Villotte, Churchill, et al., 2010; Villotte & Knüsel, 2014), thus trends of EC presence were also investigated for bilateral asymmetries when traumatic injuries were present.

4.1. Measurement error of the Coimbra method

The United States Supreme Court ruled in 1993 that expert testimony must be relevant and reliable to be admissible in the courtroom. Thereby, all international and national forensic anthropology protocols became stricter with respect to the accuracy and repeatability of methods used in forensic investigations (Christensen & Crowder, 2009). Recording methods of EC have evolved since the firsts attempts, mostly due to researchers understanding that entheses are anatomically different between them and have recognized that factors involved have a differential effect on each type of change (Villotte et al., 2016). The expectations for inter-rater repeatability of qualitative methods scoring EC are expected to reach a maximum of 80%-85% (Wilczak et al., 2017), which is considered the expected overall inter-observer and intra-observer agreement in this research.

There is no consensus about the minimal error that methods used in forensic anthropology must reach to be considered acceptable (Klales & Ousley, 2010). However, clinical studies consider that the threshold for acceptance depends on the particular context, being either 80% of agreement percentage, or Kappa values over 0.60, the desirable threshold value (McHugh, 2012; Sim & Wright, 2005). Forensic standards recognize that skeletal evidence has limitations caused by the innate variability of morphological traits, as seen in studies of sex assessment using nonmetric skeletal traits (Klales et al., 2012; Langley et al., 2018), and age-at-death estimation in which some of the features reported had Kappa values under 0.60 (Shirley & Ramirez Montes, 2015), but variability is a frequent limitation when assessing skeletal features and cannot be considered an error itself (Christensen et al., 2014). Therefore, the best practice is to include a clear statement of error rates of both the expert and the method used to evaluate admissibility in the courtroom (Christensen & Crowder, 2009), and to provide better understanding of the limitations and advantages of the methods used.

4.1.1. Inter-observer repeatability

The Coimbra method is currently the most appropriate method to record entheseal changes in fibrocartilaginous entheses (see Chapter 2), thus, it was chosen as the recording system for this research. The developers of the Coimbra method reached an inter-observer agreement percentage of 80%, a Kappa value of 0.589, and a Krippendorff’s alpha of 0.666, when considering observations of four different observers. The repeatability in this research reached an overall percentage of inter-observer agreement of 79%, a Kappa value of 0.604, and a Krippendorff’s alpha of 0.604, when considering observations of three different raters.

However, the two subsets used to measure the repeatability in this study obtained different results: 75.6% agreement, Krippendorff's alpha and Cohen's Kappa value of 0.407 with the rater less experienced in the Coimbra method, and 83.3% agreement, Krippendorff's alpha and Kappa 0.721 with the most experienced rater and one of the original authors of the method. Moreover, Kappa values are reduced when a single score is more frequently recorded than the other scores (Byrt et al., 1993; McHugh, 2012). This prevalence effect has been a factor considered when calculating repeatability of the Coimbra method (Wilczak et al., 2017). The results of Kappa and Krippendorff's alpha were nearly the same, therefore Kappa was chosen for the discussion, as it is more commonly used to measure repeatability of nonmetric features in forensic anthropology than Krippendorff's alpha (Ingvoldstad & Crowder, 2009).

Other studies that used only two raters to calculate inter-rater repeatability of the Coimbra method reported an agreement ranging from 75.2% to 90.4% (Jorgensen et al., 2020; Meco, 2018; Salega et al., 2017). The study of Salega and colleagues obtained the highest agreement of all, but one of the two raters was a developer of the method. The inter-observer agreement of the other two studies were comparable ranging from 75.2% to 78.5%. Such results were consistent with the high interrater agreement (83.3%) obtained in this research with the rater with the most experience, as Salega et al. reported, and the low agreement (75.6%) obtained with the rater with the less experience in the method, as seen in the other two studies.

Repeatability by features evidence that erosion in zone 2 (ƙ = 0.53), fine porosity (ƙ = 0.51), textural change (ƙ = 0.54), and bone formation in zone 1 (ƙ = 0.55) are the traits showing the highest inter-observer repeatability of this research, all of which are under the minimal desirable threshold for Cohen's Kappa (0.60), but performed better than some popular methods of age assessment such as the Suchey-Brooks method (ƙ = 0.47) (Shirley & Ramirez Montes, 2015). The entheseal changes showing lower repeatability scores in this study performed similarly across other studies, for instance Salega et al. 2017 reported that the percentage of inter-observer agreement of bone formation and erosion ranged from 60% to 97.5% depending on the enthesis analyzed. Therefore, more training and discussion about those features is recommended before applying the Coimbra method.

A study of inter observer error of Phenice traits for sex estimation obtained a percentage agreement between 41% to 65% and Kappa values between 0.20 and 0.26, depending on the features analyzed (Klales & Ousley, 2010). Shirley and Ramirez Montes (2015) found that scoring by trait increases inter-observer repeatability rather than score by complete phases when assessing morphological features of the pelvis to estimate skeletal age. Therefore, recording by feature is suggested to be a better methodological approach for analysis of morphological skeletal features.

The inter-observer repeatability also showed disagreement in non-observable data, as has been evidenced in other studies (Mariotti et al., 2004, 2007a; Salega et al., 2017; Villotte & Lopreno-Perréard, 2012; Wilczak et al., 2017). The extension of entheses may be difficult to assess when morphological variations or taphonomic processes alter the expected appearance. Thus, clear delimitations of each enthesis, and definitions of zone 1 and zone 2, will help to increase agreement of what is considered observable and non-observable (Wilczak et al., 2017).

The difference in the results between experienced and non-experienced raters evidenced that prior knowledge of the anatomy of the enthesis and level of training on the Coimbra method affects the repeatability (Wilczak et al., 2017). How the method was learned, and the amount of practice and discussion regarding each feature before data collection, may be major issues affecting the repeatability. Although some of the features recorded by the Coimbra method are used by methods assessing other skeletal elements, like “pitting” recorded in joint surfaces which is similar to porosity (Villotte et al., 2016), it is likely that the normal variability of the entheseal surface may confuse raters when scoring changes (Wilczak et al., 2017). Wide variability associated with morphological features has been noted in methods to estimate age and determine sex, but repeatability is increased when the complete skeleton is analyzed (Kimmerle, Prince, et al., 2008; Klales et al., 2012), and each one of the features are discussed in detail (Wilczak et al., 2017).

Assessment of entheseal changes has been absent or minimal in forensic analysis, so the introduction of a new method can be challenging. As seen in most studies, the Coimbra method as any other method requires training, practice, and knowledge of the entheseal morphology to reach the inter-rater agreement required by forensic standard. Nevertheless, the Coimbra method has reached the desirable threshold (80%) of repeatability for assessment of morphological features. Despite the fact that one of the three raters in this dissertation (EB) was not directly trained by the developers, the overall agreement (79%) was higher than other EC recording methods that obtained an inter-observer agreement ranging between 50% and 80.4% when it was measured using a non-developer rater or someone who was not directly trained by a developer (C. B. Davis et al., 2013; Villotte & Lopreno-Perréard, 2012). Moreover, this method has the strength of recording each feature separately, which allows investigators to focus their efforts on the most confusing traits to further improve repeatability.

4.1.2. Inter-observer repeatability of other research

The percentage agreement of all entheses of the five tests showed similar trends – an average percentage agreement of 78.6% (Table 4-1). This was excepting the high agreement between CH and MA of the BF feature in both zones (1, 88%, and 2, 89%), and the low agreement for ER (Z2) in both the CH vs MA (67%) and the EB vs MA (55%) comparisons (Figure 4-1) showing that some features can be easier to identify than others. However, the frequency of features may differ between subsets based on population variability and average age of the skeletal collection, which in turn, affects the overall percentage agreement. Accordingly, European skeletal collections represent mostly white individuals with an average age of 50 years and older, while the Colombian skeletal collections is mostly composed of non-white individuals with age at death of 30 years or younger (Isaza & Monsalve, 2012; Sanabria Medina et al., 2016). The two subsets used to test inter-observer agreement in this research came from two different populations, Portugal, and Colombia. The Portuguese subset had an average age of death of 71.1 years, while the individuals from the Colombian subset had an average of 46 years.

Trends of the *subscapularis* enthesis of both the CH vs MA, and the EB vs MA subsets, were consistent with the trends for all entheses, except for the agreement of CH and MA for the ER (Z2) feature (69%), which showed better results compared to the other studies (Figure 4-2). The common extensor origin evidenced that agreement in the BF (Z1) was as high in the CH vs MA (92%) as it was in the Coimbra B tests (87%) (Figure 4-3). The agreement in the ER (Z2) was consistently low for both the CH vs MA (64%), and the EB vs MA (63%) subsets, compared to the other tests. Except for the EB vs MA subset, all the other subsets belong to skeletal collections with an average age of 70 years or older.

Table 4-1. Comparison of inter-observer percent agreement results to Wilczak et al. 2017; Salega et al. 2017; and Meco 2018.

		BF Z1	ER Z1	BF Z2	ER Z2	FPO	MPO
Coimbra B, overall agreement 80%							
N= 10	Subscapularis	62	95	83	77	68	90
	CEO	87	92	68	70	72	77
	Both entheses	74	93	76	73	70	83
Meco, overall agreement 80%							
N= 22	Subscapularis	73	87	59	64	91	91
	CEO	69	68	82	91	96	96
	Both entheses	71	77	71	78	93	93
Salega et al. 2017, overall agreement 83%							
N= 20	Subscapularis	72.5	78	60	80	85	77.5
	CEO	78	90	90	87.5	100	100
	Both entheses	75	84	75	84	93	89
CH vs MA, overall agreement 80%							
N= 36	Subscapularis	83	81	97	69	69	81
	CEO	92	92	81	64	72	83
	Both entheses	88	86	89	67	71	82
EB vs MA, overall agreement 70%							
N= 40	Subscapularis	58	80	65	48	68	78
	CEO	75	93	65	63	65	85
	Both entheses	66	86	65	55	66	81

Krippendorff's alpha overall value was calculated using both the *subscapularis* and the common extensor origin entheses for comparison to other researchers. The study by Salega and colleagues (2017) was excluded from further comparison as it did not include data on Krippendorff's alpha. Overall, the difference in the agreement was not large in terms of percentage (10% difference), but the Krippendorff's alpha results of CH vs MA and EB vs MA tests were significantly different from one another. While the former showed the highest value of all the tests, alpha 0.699; the latter obtained the lowest value, alpha 0.039 (Table 4-2). Only the Krippendorff's alpha values of CH vs MA, and the Coimbra B test, were above the limit suggested for acceptance.

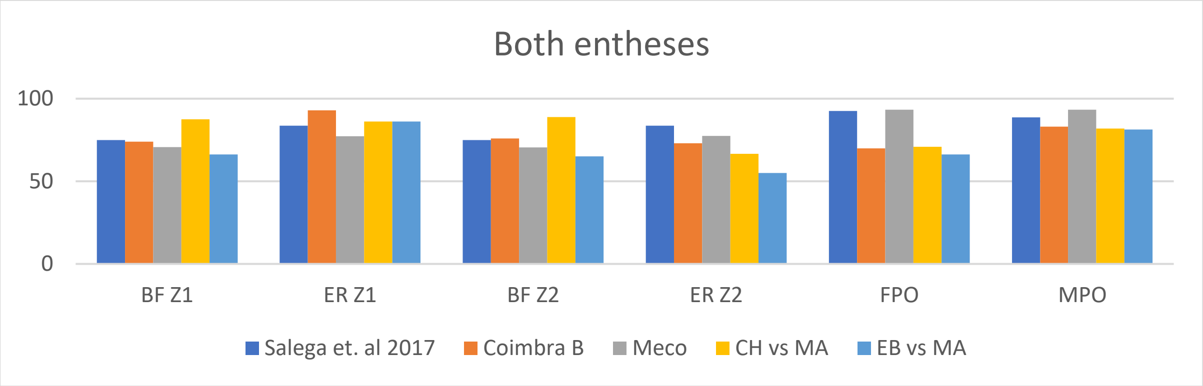


Figure 4-1. Comparison to other researchers of percentage agreement by features of all entheses.

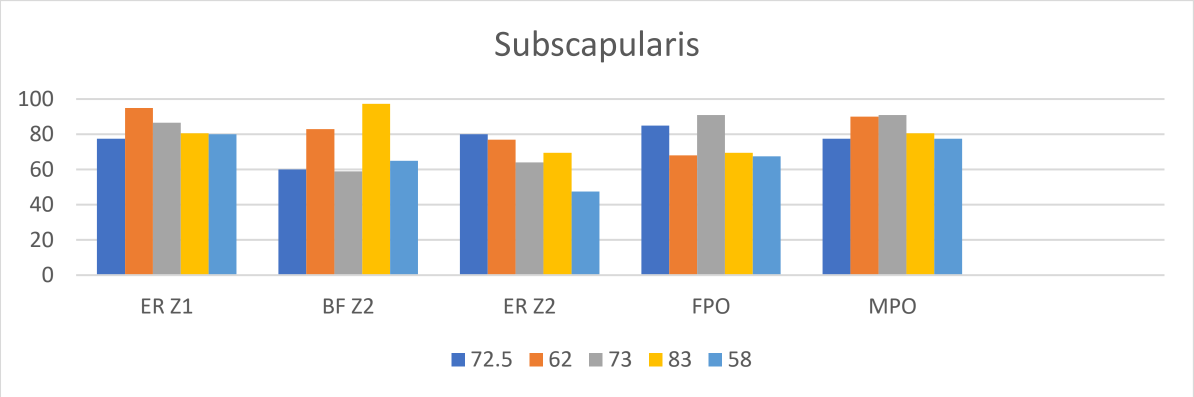


Figure 4-2. Comparison to other researchers of percentage agreement by features of subscapularis.

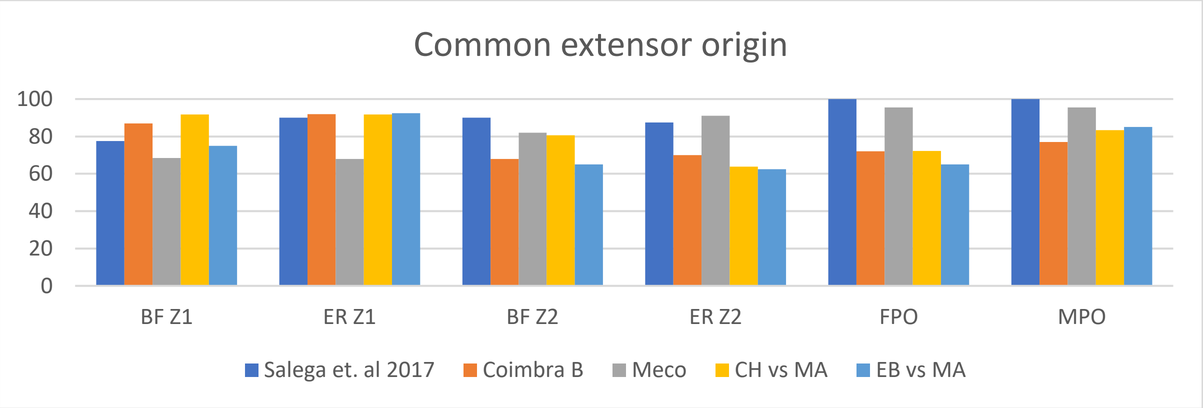


Figure 4-3. Comparison to other researchers of percentage agreement by features of common extensor origin.

Table 4-2. Comparison of Krippendorff test of all inter-observer tests.

	n	Score categories	Krippendorff's alpha
Coimbra B	10	3	**0.666**
CH vs MA	36	3	**0.699**
EB vs MA	40	3	0.039
Meco	11	-	0.034

n: individuals included. Krippendorff's values in bold were higher than 0.667.

4.1.3. Intra-observer repeatability

Intra-observer repeatability calculated for the Coimbra method was similar across several studies ranging from 79.3% to 96% (Jorgensen et al., 2020; Meco, 2018; Palmer et al., 2019; Salega et al., 2017; Wilczak et al., 2017). This study evidenced overall agreement of 87%, Kappa value of 0.738, and Krippendorff's alpha of 0.738. The intra-observer agreement of the Coimbra method obtained in this research, and others, is 80% or higher. Such agreement denotes consistency of all raters to score EC using this method. Considering the high intra-observer agreement, it is likely that the low repeatability between observers highlights disagreement in the interpretation of the terminology (Wilczak et al., 2017). Developers of other EC scoring methods obtained an intra-observer agreement between 71.9% (Mariotti et al. 2007) and 92%, and Kappa 0.86 (Villotte, 2006). Widely applied methods assessing morphological features of skeleton can reach a Kappa value between 0.579 to 0.694 depending on the feature observed (Klales et al., 2012), which shows that the repeatability of the new Coimbra method is within expectations for qualitative methods that record morphological features.

In summary, nonmetric methods are proven to be more sensitive to the observer's subjectivity than metric methods (Kotěrová et al., 2018). However, forensic anthropologists are trained to recognize abnormal and normal characteristics of human bones, and to assess the variability of morphological features. The skill of forensic anthropologists transforms human variability into a strength of forensic anthropology and not a weakness. This research obtained an overall intra and inter-observer agreement of the Coimbra method above the desirable threshold for clinical studies (Kappa =0.60), which is similar to the values reported by other studies (Jorgensen et al., 2020; Meco, 2018; Salega et al., 2017), including the results obtained by the developers of the method (Wilczak et al., 2017). Despite the prevalence effect, the consistency of the repeatability values, discussed earlier, evidenced that this method can be applied in the forensic context.

Variability of the normal morphological features, such as the entheseal surface, is a limitation of this method and should not be considered an error (Christensen et al., 2014). To address such limitation there must be full recognition of the appearance of each feature and the most common morphological variations on the entheseal surface that are not considered entheseal changes before applying the method (Henderson, Wilczak, et al., 2017). Additionally, as with any other metric and nonmetric method applied in a forensic context, error rates and limitations allowing assessment of proof admissibility must be clearly provided (Christensen & Crowder, 2009).

4.2. Population variability

International protocols rule forensic practice and establish the basic requirements that all analyses must satisfy. Nevertheless, academic research and forensic experiences around the world have shown that population variability affects some biological parameters more than others e.g., sex, height, body size (Campanacho, 2016; Rissech et al., 2012; Rivera-Sandoval et al., 2018). More accurate results are obtained when such parameters are assessed using population-based standards or the accuracy of widely used methods is tested in each forensic context (Işcan et al., 1998; Kimmerle & Jantz, 2008; Ubelaker, 2008). Context specific standards are important not only because the population variability may influence the normality and frequency of certain skeletal traits, but also because the human and technical forensic resources available in each country varies considerably (Ubelaker, 2015). Therefore, understanding the general patterns of EC within the Colombian population can increase their potential usefulness in the osteological analysis.

The individuals from the NILMFS skeletal collection were born between 1940 and 1987 and died and were buried in Bogota D.C. between 2005 and 2008. The UdeA skeletal collection is made up of individuals who died between 2003 and 2005 and were buried in Medellín. As discussed before (see Chapter 2), the genetic admixture in Colombia is highly variable (Ossa et al., 2016), and other socioeconomic factors such as urban violence (Franco et al., 2012) and economic growth (Meisel & Vega, 2007) have had different characteristics in both cities and may explain some differences observed between the skeletal collections. The differences in EC frequency obtained in this research are medium at best, and do not support exclusion or inclusion of a given individual within a geographic zone i.e., Medellín or Bogota D.C. However, the differences highlight that skeletons are affected by factors that may vary between populations, even when such populations appear to be similar genetically and socially (Nikita & Chovalopoulou, 2017). Forensic anthropologists must be aware of such subtle factors when assessing morphological features as they appear to influence the results (Campanacho, 2016; Nikita & Chovalopoulou, 2017; Rivera-Sandoval et al., 2018).

It has been repeatedly suggested that mechanical stimuli triggers enthesitis in individuals with and without predisposition to bone forming diseases, but those with a predisposition have lower physiological limits and experience greater changes (D’Agostino & Terslev, 2016; McGonagle, Marzo-Ortega, O’Connor, Gibbon, Pease, et al., 2002; Schett et al., 2017). The entheses in the upper limbs are thought to better reflect manual labor through bilateral asymmetries (Gosens & Hofstee, 2009; Notarnicola et al., 2012; Palmer et al., 2016; C. N. Shaw & Stock, 2009; Villotte, Castex, et al., 2010), while the entheses of the lower limbs appear to be more prone to develop enthesitis, mostly associated with mechanical stimuli of locomotion (D’Agostino et al., 2009; Kirkpatrick et al., 2017; Kumai & Benjamin, 2002; Menz et al., 2008; Schett et al., 2017). This study did not seek to understand biomechanical differences between the two skeletal collections, and the antemortem information available did not provide data regarding the last known occupation or hobbies of all individuals, that could help to explain biomechanical differences between the two samples. Considering the purposes of this research, and the complex economic dynamics of both cities Bogota D.C. and Medellin, it is complicated to associate the differences in the trends of entheseal changes with biomechanical loads or economic activities. Nevertheless, the biological and socioeconomic differences between the two cities described earlier (see Chapter 2) could help to understand the results.

The general patterns of EC within the two skeletal collections have few differences, all weak, between them. Most of the differences show that the NILMFS collection has a higher frequency of EC than the UdeA collection. The presence of bone formation is frequent in the entheses of the left rotator cuff and left-hand muscles of the NILMFS collection, while erosions are more frequent in the *biceps brachii* insertion and knees of the individuals from the UdeA skeletal collection. Differences in presence of textural change are seen in both collections depending on the enthesis. The presence of fine porosity is higher in some entheses on the right side of the individuals from the NILMFS collection compared to the presence observed in the UdeA collection.

Trends change and become stronger when age is taken into consideration: the UdeA has a higher frequency of EC than NILMFS, and the differences seen between the young adults are weak, while the middle adults have medium effect size differences. Another important finding is that EC trends change by age range, suggesting that population variability needs to be analyzed according to the age range. For instance, the presence of bone formation in the forearms and right foot of the young individuals of the UdeA collection may indicate a mechanical rather than pathological origin (further discussed below). Whereas the differences between middle adults show that the UdeA have more erosions in both forearms and textural change in the lower limbs than their counterparts in the NILMFS. McGonagle and colleagues (2008) found that bone formation and erosion are two parts of the enthesitis process and are temporally unpaired, bone formation is usually seen in the fibrous points of the enthesis where high tensile forces act, while erosion occurs mostly where fibrocartilage is prominent and compression forces are concentrated. This separation in time and location within the entheseal surface of the bone formation and erosion may explain the presence of bone formation in young adults and erosion in middle adults of the UdeA skeletal collection.

The old adults have opposite trends: the presence of fine porosity and textural change in the right forearm was more common in individuals from the NILMFS skeletal collection. Textural change is also frequent in the iliopsoas insertion of the individuals from the NILMFS. However, the sample from the NILMFS collection included a higher proportion of individuals older than 50 years old than the sample from the UdeA collection, which may affect the results.

Although it is unclear which factors have a greater effect on the entheseal surface, the results of this study are consistent with the literature in which age, microanatomy, biomechanical loads, and pathologies may be major factors (McGonagle et al., 2008). The differences between the two skeletal collections are further discussed by anatomical region.

4.2.1. Upper limbs

The general trends of EC presence in the upper limbs of each of the skeletal collections were consistent with the literature, in which bone formation and erosion are the features most associated with aging. The differences of EC presence between the two skeletal collections without controlling for age showed fifteen differences between the two collections (Table 3-11), most of which evidenced that ECs were more frequent in individuals from the NILMFS skeletal collection. Seven out of the fifteen differences are significant and had weak effect size and the remaining twelve differences were all negligible. Therefore, the discussion focuses only on the seven features that were slightly different between the two skeletal collections.

The greatest difference between the two collections is seen in the right arm, where six out of the seven cases are located. Four of those six cases show that individuals from the NILMFS are more prone to textural change in the *biceps brachii* insertion, fine porosity in both the *supraspinatus* insertion and the common extensor origin, and erosion in zone 2 of the common flexor origin. The remaining two weak differences on the right arm are the greater frequency of bone formation in zone 1 and erosion in zone 2 in the insertion of the *biceps brachii* of individuals from the UdeA skeletal collection. The only feature with a difference in the left arm is the higher frequency of bone formation in zone 2 in the common flexor origin in individuals from the NILMFS collection.

In the upper limb, only the *biceps brachii* was found to have differences in textural chance frequency. The etiology of textural change is not completely understood, there are nevertheless relevant conclusions regarding lesions to soft tissue associated with the enthesis reactions. It has been noted that textural change and fine porosity are more frequent in entheses of young individuals, leading to the suggestion that such features may have a developmental origin (Henderson, Mariotti, et al., 2017). However, the results of the GLM of this study found a different pattern in the right common flexor origin in which age affects the presence of textural change, but it was mostly observed in middle adults (Table 3-9). Therefore, based on the finding of this research the presence of this feature in the enthesis of the *biceps brachii* could not be attributed to developmental origin alone.

As described by the new Coimbra method (see Chapter 2), textural change refers to a diffuse granular texture that must be extended at or over 50% of the entheseal surface to be recorded (Henderson et al., 2016). Accordingly, the etiology of textural change could be associated with lesions affecting a wide area of the entheseal surface such as thickening of the tendon, ligament, or capsule at insertion, and hypoechogenicity[4]. Considering that the etiology of both entheseal thickening and hypoechogenicity is associated with active inflammation (Terslev et al., 2014), it is likely that the enthesis response could result in mineralization of uncalcified fibrocartilage as originally proposed by Villotte and colleagues (2016). The figure 2 of Kaeley (2020) evidenced that the origin of the patellar ligament is thickened, with hypoechogenicity and the adjacent bone cortex has irregularities/periosteal reaction. The same enthesis showed vascularity in a power Doppler image indicating an active inflammation. Other studies have produced opposite results of no frequency, or low frequency, of power Doppler signals associated with hypoechogenicity or entheseal thickening (Di Matteo et al., 2020; Falsetti et al., 2020). Di Matteo et al. (2020) concluded that absence of signals when soft-tissue inflammatory lesions are present, can be indicative of a previous enthesitis. Moreover, entheseal thickening and/or hypoechogenicity lesions were present in 10.4% of entheses of healthy and asymptomatic individuals, in 48.4% of entheses of individuals with spondyloarthopahies diseases, in 17.8% of the entheses of individuals with autoimmune disease (Di Matteo, Filippucci, Cipolletta, Satulu, et al., 2018) and 11% of the entheses of individuals with metabolic disorders (Falsetti et al., 2020), which evidenced that inflammation at enthesis is a common lesion associated with both biomechanical and pathological stressors.

Fine porosity was found in two different entheses in the upper limb, the *supraspinatus*, and the common extensor origin. Its etiology is likely to be normal vascularization of the entheseal surface or an initial reparative response. The regular inflammatory process associated with the enthesis starts with a mechanical or pathologic stressor, followed by vasodilation of transcortical microvessels, then an inflammatory reaction of the bone marrow takes place,

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[4] Hypoechogenicity is defined as *"loss of tendon fibrillar pattern at insertion*" (Terslev et al., 2014)

which activates immune cells, and finally new bone is formed (Schett et al., 2017). Benjamin and colleagues (2007) showed that blood vessels pass from soft tissue to bone, and vice versa, using previously formed micropores. Such micropores in fibrocartilaginous enthesis5entheses, which are between 100 to 400 μm wide, appear to be normal physiological and biomechanical features that promote vessel invasion in regions with a thin cortical shell allowing the enthesis to maintain direct contact with bone marrow (McGonagle et al., 2009; Schett et al., 2017), and to increase the blood flow required to initiate the reparative response (Benjamin et al., 2007; D'Agostino & Terslev, 2016). Therefore, porosities observed in the entheseal surface of the dry bone are likely to be blood vessel channels activated by inflammation (Henderson, Mariotti, et al., 2017; Villotte et al., 2016; Wilczak et al., 2019). However, it remains unclear if fine porosity is related to the normal blood vessel channels or their appearance is intensified during the vasodilatation phase. It is also not known whether the pores are temporary or permanent features.

The origin of erosions in the *biceps brachii* insertion and the common flexor origin remains unknown. Erosions on the entheseal surface may relate to failures in the healing process during the inflammatory response. This failure stimulates the deposit of calcium crystals (Sansone et al., 2016) and are commonly found in the shoulder and hip joints, but they can be present within any tendon of the body (Draghi et al., 2020). A small percentage (5%) of calcifying tendinopathy in the shoulder has been reported to reach the bone cortex causing structural damage to the enthesis (Nogueira-Barbosa et al., 2015). According to clinical literature calcifications in the distal enthesis of the *biceps brachii* are rare, and no cases of calcifications in the common flexor origin have been reported (Draghi et al., 2020). Another etiology suggested for erosions is bone marrow edema during early stages of enthesitis (Eriksen, 2015; Hayter et al., 2013; McQueen et al., 1999), but few cases have been reported in the *biceps brachii* and they were mostly associated with psoriatic arthritis. No cases of erosion related with bone marrow edema have been reported in the common flexor origin (I. Eshed et al., 2007). Moreover, mechanical or degenerative related diseases are more frequently associated with enthesitis in the elbow than rheumatic diseases (I. Eshed et al., 2007). Therefore, it is more likely that erosions in those entheses may be related to the effect of compressive or shear forces where fibrocartilage is abundant (McGonagle et al., 2008).

The presence of bone formation in some entheses in the upper limbs has been explained, up to 44%, by aging (Henderson, Mariotti, et al., 2017; Salega et al., 2017; Wilczak et al., 2019). While in entheses of the lower limbs the new bone formation has also been associated with tension and compression forces (Benjamin et al., 2000; Czegley et al., 2018; Jacques et al., 2014; Kumai & Benjamin, 2002), and attributed to pathological inflammatory responses in individuals genetically predisposed to spondyloarthropathies (Kehl et al., 2016; McGonagle et al., 2008; Polachek et al., 2018). This research found a slightly higher frequency of bone formation in most of the entheses in the upper limbs of individuals from the NILMFS than the individuals from the UdeA skeletal collection, except in *biceps brachii*. Considering that the presence of bone formation is affected by genetic predisposition, and that Medellin and Bogota D.C have different proportions of genetic admixtures (Ossa et al., 2016), it is likely that the differences between the two skeletal collections are associated with the genetic predisposition of some individuals to form new bone when low levels of mechanical stimuli are applied (McGonagle et al., 2008; Polachek et al., 2018; Schett et al., 2017). Consistently, Londoño et al. (2018) found that individuals from Bogota had a higher prevalence of rheumatoid arthritis (2.60% vs 0.69%), and rheumatic regional pain syndrome[5] (2.67% vs 0.32%) than individuals from Medellin, while ankylosing spondylitis is rarely present in Bogota D.C (0.08%) and occasionally seen in Medellin (2.20%). Although most spondyloarthropathies cause pathological enthesitis, the skeletal manifestations vary between the different diseases and are difficult to accurately assess in the dry skeleton (Rothschild et al., 1999; Samsel et al., 2014; Villotte & Kacki, 2009). However, ankylosing spondylitis has greater manifestation in the entheses in the lower limbs (Benjamin & McGonagle, 2001; D'Agostino & Olivieri, 2006), and may be explaining the differences observed in the higher frequency of bone formation in the ankle/foot joint complex of the young and middle adults of the UdeA skeletal collection (further discussed in the next section).

The differences between the two collections (all only weak or medium effect size) are stronger when age is controlled for (Tables 3-12 and 3-13) and confirm that the difference is focused on the entheses involved in the forearm movements. The comparison by age range found eleven

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[5] Rheumatic regional pain syndrome includes rotator cuff, epicondylitis, epitrocleitis, Quervain's disease, carpal tunnel syndrome, Dupuytren's disease, trochanteric bursitis, anserine bursitis, Achilles tendinopathy, plantar heel pain.

differences between the two collections, but only six of them have medium effect size. Most of the features (72%) show that the biceps and *triceps brachii* insertion have greater presence of EC in individuals from the UdeA skeletal collection. The differences are weak in young adults, but become stronger in middle and old adults, which suggests that stressors are present from early adulthood and are enhanced by aging. Textural change in the *biceps brachii* and fine porosity in the common extensor origin are more frequent in old adults from the NILMFS collection, only the textural change is also present in middle adults. Regardless of the etiology, there is a difference between the two collections associated with the entheses responsible for the supination, flexion, and extension movements of the forearm.

Consistent with literature, entheseal changes were commonly seen in the *biceps brachii* insertion (Nolte & Wilczak, 2013), which suggests that this muscle is pushed to its physiological limits (Acosta et al., 2017). In addition to its biomechanical relevance, the complex and highly variant anatomy of the *biceps brachii* insertion may play an important role in EC presence.

Given the discussion above regarding etiology associated with these features and the entheses involved, it is likely that mechanical stressors of the forearm movements of male individuals from both skeletal collections are different between each other and ECs become more evident with aging. However, the effects of BMI or physical activity are not controlled for in these trends, thus, the differences between the two skeletal collections must be further explored in future research. On the other hand, the genetic differences may trigger pathological entheseal changes in certain insertions, and normal anatomic variability could also play an important role.

4.2.2. Lower limbs

The entheses in the lower limbs evidence that the greatest difference between the two collections is in the left leg, where four out of six features, all of which had weak differences, are located (Table 3-31). Considering that the upper limbs show the most differences in the right side, and that the lower limbs showed the opposite trend, it is likely that upper and lower limb entheses either have no equal responses or stressors are not similar (Schett et al., 2017).

For instance, the entheses in the lower limbs appear more affected by spondyloarthropathies than the entheses in the upper limbs (I. Eshed et al., 2007; Kumai & Benjamin, 2002; Schett et al., 2017). Biomechanically, the upper limbs tend to be right-dominant (Ardila & Rosselli, 2001; C. N. Shaw & Stock, 2009) while asymmetry in the lower limbs is still under discussion (Sadeghi et al., 2000).

In general, the UdeA skeletal collection show greater association (although weak) with erosions in the *quadriceps femoris*, and textural change in the gastrocnemius and *triceps surae* than the NILMFS collection, but the two entheses of the foot show the opposite trend, where presence of fine porosity in the *triceps surae* and erosions in the plantar fascia entheses are greater in the individuals from the collection in Bogota D.C. If enthesitis in the lower limbs are related mostly with locomotion loads, then the terrain characteristics of both cities may contribute to explain the variability observed (Acosta et al., 2017). Given their location in the Andes, Bogota D.C and Medellin share terrain characteristics, and both cities have neighborhoods that are predominantly impoverished located high in the mountains, where most of the working class reside i.e., neighborhoods that are categorized between strata 1 to 3 in the national socioeconomic stratification system[6], and are the neighborhoods that receive an assortment of government subsidies. The main terrain difference between both cities is the altitude above sea level. Bogota D.C is located at 2630m compared to Medellin at 1495m. Although high altitude can be associated with muscle fatigue and lack of blood oxygen (Amann et al., 2007; Netzer et al., 2013), it is unclear if higher elevation contributes to EC presence as observed in the entheses of the foot. Moreover, it is unknown if 1100 meters difference is enough to cause population variability.

As seen in the upper limbs, the trends in the entheses of the lower limbs are stronger when age is taken into consideration (Table 3-34). Iliopsoas and *vastus lateralis* entheses are more frequent in the middle and old adults from the collection in Bogota D.C than the individuals from the collection in Medellín. The difference observed in the iliopsoas insertion may be

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[6] The socioeconomic stratification system in Colombia divides all urban and rural areas into 6 categories: strata 1 are the areas with the lesser quality and strata 6 the households with best conditions. Although the stratification is not based on the income of its habitants, there is a notion that this classification is an indicator of the payment capacity of them (Cantillo-García et al., 2019).

related with the greater prevalence of mechanical low back pain (10.15% vs 4.39%) and inflammatory low back pain (1.29% vs 0.49%) reported in Bogota D.C (Londoño et al., 2018). Nourbakhsh and Arab (2002) found an association between the strength of the iliopsoas muscle with low back pain in male individuals, where weakened muscles reduce the stability in the lumbosacral area, which in turn, increase signals of pain receptors in the surrounding soft tissue, causing pain (Bachrach, 1997). Other research has found that weakened muscles are associated with tendinopathies and lesions in the entheses (H. Shaw & Benjamin, 2007; Wilder & Sethi, 2004). The cause of the difference observed in the insertion of the right *vastus lateralis* of middle adults remains unclear.

As discussed above, Medellin has a higher prevalence of ankylosing spondylitis than Bogota D.C that could stimulate the presence of EC in the lower limbs. Skeletal signs of this disease are likely to be evident after 50 years of age, therefore, most of the individuals with ankylosis of the sacro-iliac joint or vertebrae may have been excluded from the sample, creating a bias within adults over 50 years. Considering the higher prevalence of ankylosing spondylitis in Medellin, it is suggested that the presence of bone formation in young and middle adult individuals from the UdeA skeletal collection could be related to an early onset of this disease, maybe stimulated by biomechanical loads from young adulthood that reaches a significant presence during middle adulthood.

Although it is not clear which or how the factors are affecting the presence of EC in individuals from different populations, it is likely that genetic admixture and quality of life are playing a role. During the 1980’s Colombia suffered widespread violence related to drug-trafficking activities perpetrated by the two most powerful drug cartels of the Colombian history, the Medellín Cartel, led by Pablo Escobar and the Cali Cartel, led by the Rodriguez-Orejuela brothers, increasing violence rates of Cali and Medellin. Bogota D.C remained on the periphery of the drug-violence phenomenon, experiencing lower homicide rates than Cali and Medellin (Franco, 2003; Franco et al., 2012). Studies of secular trends in violent environments have demonstrated that psychosocial stress can delay the age at menarche, even when individuals have not been personally involved in the violence (Prebeg & Bralic, 2000; van Noord & Kaaks, 1991). Female’s sexual maturation age in Colombia has suffered deceleration during the periods with higher rates of homicide, particularly in those women that were in their early childhood between 1979 and 1991 (Villamor et al., 2009). The stature of male Colombians increased over the 20th Century and was not affected by the periods of the most horrific violence. But a deceleration of male's stature was observed in individuals born between 1970 and 1974, which coincides with a period of noticeable increase in food prices (Meisel & Vega, 2007). Meisel and Vega found that during the last decades of the 20th Century Bogota D.C. had greater economic growth and greater increase of height than Medellin. Although the literature is contradictory regarding the biological impact of generalized violence on male and female individuals (Meisel & Vega, 2007; Prebeg & Bralic, 2000; van Noord & Kaaks, 1991), there is a consensus in that high psychosocial stress or slow economic growth following violent environments affect growth and maturation, and that Medellin has had worse quality of life conditions than Bogota D.C., which may explain some of the differences in the EC trends.

The violence and economic factors have caused important internal migratory movements in Colombia, which in general, create urban migration from nearby towns (Cuervo et al., 2018). National census and demographic studies have shown that Bogota D.C and Medellin have had a different pattern of internal migration during the 20th Century (Villamor et al., 2009). Medellín has received mostly people moving short distances who were born in the same department or in areas with historical and genetic ties such as the Coffee Region[7] (Castro-Escobar, 2016; Ossa et al., 2016), while Bogota D.C had received a greater volume of migrants coming from all departments of Colombia (Cuervo et al., 2018; DANE, 2008). Therefore, genetic admixtures, and other factors affecting EC presence are likely to maintain the same patterns.

Normal morphological variations may be another factor to consider when analyzing EC. Some non-metric traits are associated with normal vascularization that can be genetically predisposed and its presence varies depending on the population under study e.g., parietal foramen linked to Santorini's vain (Mann et al., 2016; Valente & Valente, 2004), encouraging the idea that porosities on the entheseal surface may be normal morphological variations without pathological implications. Moreover, the anatomy of some entheses, such as the *biceps brachii* insertion and *quadriceps femoris*, is highly variable (Fogg et al., 2009; Henderson, Wilczak, et

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[7] The Antioquia's colonization area, "Colonización Antioqueña" in Spanish, includes the departments of Quindio, Risaralda and Caldas, known as the coffee region or "eje cafetero" in Spanish.

al., 2017; Toumi et al., 2014; Waligora et al., 2009). It is unclear whether some normal anatomical variations could stimulate the presence of EC or could have a similar appearance as the features recorded in the Coimbra method. Genetic predisposition to pathological bone formation seen in seronegative spondyloarthropathies diseases, DISH, and its relationship with EC, mostly enthesophytes, have been frequent factors considered in the osteological research (X. Chen et al., 2007; Henderson, 2008; Jurmain et al., 2012; Mazza, 2019), but none of the entheseal changes observed in the fibrocartilaginous entheses have been related to a wide range of normal morphological variations.

In summary, population variability encompasses an array of biological, social, economic, and geographical elements that are complex to understand. This study evidenced that some differences in the right upper limb and left lower limbs had an onset during young adulthood but became more evident in individuals older than 50 years old. It is unclear if one or more of the factors discussed has a greater effect on the presence of EC.

One limitation of this study is that BMI was not measured because antemortem data of weight was not available and estimates of BMI based on skeletal material are rarely performed by forensic anthropologists. Osteological studies use the femoral head diameter and regression formulae to calculate lean body mass. However, those formulae were developed based on body proportions seen in white populations (Auerbach & Ruff, 2004; Grine et al., 1995; Ruff et al., 1991), and are inaccurate to predict adiposity (Wescott, 2014). Moreover, recent studies indicate that body build, body composition, and fat distribution differ among populations (Nikita & Chovalopoulou, 2017; Rush et al., 2009), therefore using the current regression formulae which have not been adjusted or tested in the Colombian population, mostly a non-white population, may introduce additional bias to the results. Antemortem information regarding physical activity, nutritional status, and residential history is missing, limiting the demographic profile of both skeletal collections.

4.3. Antemortem trauma

The primary aim of this thesis was to strengthen the contribution of forensic anthropology to the personal identification process in Colombia by understanding the effect of antemortem trauma in EC presence, and to estimate the strength of the effect. According to the origin of EC found in the literature, it was expected to observe more presence of erosion, fine porosity, and macro-porosity in individuals with antemortem trauma (Table 1-3). To recap, erosions on the entheseal surface are linked to failures in the self-healing process (Sansone et al., 2018), compression forces (McGonagle et al., 2008), or bone marrow edema (I. Eshed et al., 2007). Contusions are mostly caused by compression forces; therefore, erosions can be expected to be stimulated by trauma. Porosities are associated with vascularization when a reparative response has started, indicating that a mechanical or pathological lesion has occurred (Benjamin et al., 2007; Schett et al., 2017). Therefore, it is likely that fine porosity and macro-porosity will be observed in conjunction with a lesion. However, it is unknown if the appearance of EC varies from the time of lesion to death of the individual. Dyment et al. (2015) found that turnover rate of mineralization is nonexistent in adulthood evidencing a poor healing response, but De Miguel et al (2011) reported that erosions in spondylarthritis patients are likely to disappear within 6 months.

The results indicated that fine porosity, textural change, erosion in zone 1, and macro-porosity, in that order, were the features showing association (all weak) with antemortem trauma (Table 3-64 and Table 3-71). Except for textural change, the association seen with the other three features is consistent with the clinical literature.

Studies have demonstrated that both the enthesis and the bone are affected by several factors such as age, sex, BMI, mechanical load, nutrition, and development (Acosta et al., 2017; Bakirci et al., 2020; Britz et al., 2009; Crowder, 2013; Currey et al., 1996; Godde & Taylor, 2013; Goliath et al., 2016; Pfeiffer, 1998; Wilczak, 1998). As such, it is essential that the skeletal features indicating an enthesis repair response such as fine porosity, or failures during the self-healing response such as erosions, are analyzed taking into account the anatomy of the enthesis (Benjamin et al., 2004), the underlying bone structure (Toumi et al., 2006), and a possible weakening of soft-tissue as a consequence of a single injury, or repetitive injuries (Mendiguchia et al., 2013; Schmitt et al., 2012; Wilder & Sethi, 2004), besides aging and BMI. Likewise, the forensic analysis would benefit from complete antemortem information regarding physical activity during skeletal maturity and adulthood, which can contribute to a better understanding of the individual’s physiological thresholds for presence of entheseal changes (Acosta et al., 2017; Schlecht, 2012; Tatara et al., 2014; Thomopoulos et al., 2007), and bone maintenance (Frost, 1987; Karakostis et al., 2019). While history of lesions will potentially allow forensic anthropologists to focus the biomechanical analysis on the injured zones and obtain more accurate biological profiles.

The EC that indicates association with antemortem injuries showed three different patterns: presence of EC in the same joint complex in which the lesion was observed; presence of EC in the same limb, but in a different joint complex than the injury was exhibited; and presence of EC when an injury was exhibited in the opposing limb. However, the cases supporting these patterns are limited, therefore further testing is needed to determine whether there is causal relationship between the skeletal evidence of antemortem trauma and the presence of ECs.

4.3.1. First pattern

The presence of both entheseal changes and antemortem trauma in the same joint complex was observed in three out of the nine associations found (33%). These associations were the presence of macro-porosity in the left common extensor origin when the left elbow was injured (Table 3-64) and presence of fine porosity in both the left and the right *quadriceps femoris* when the knee exhibited antemortem trauma (Table 3-71). Considering that those features were observed in the same joint complex as the lesion, it is presumed that the porosities on the entheseal surface are linked to early stages of the inflammatory response (Henderson, Mariotti, et al., 2017; McGonagle, Marzo-Ortega, O’Connor, Gibbon, Hawkey, et al., 2002). However, all antemortem lesions recorded in this research showed macroscopic skeletal evidence of completed healing processes indicating that the lesions occurred at least 6 months prior to death (de Boer et al., 2015; Shirkhoda et al., 1995). Accordingly, a possible entheseal inflammation near the lesion site could be associated with the weakening of muscles after the injury (Hsu & Siwiec, 2020; Mendiguchia et al., 2013; Schmitt et al., 2012).

The origin of macro-porosity is more uncertain than the origin of fine porosity. Macro-pores are defined in the new Coimbra method as pores with a diameter larger than 1mm, which are rare features both histologically and in dry bone observations (Benjamin et al., 2007; Wilczak et al., 2017). Their development may involve additional factors, such as pathological conditions, or be linked to early stages of degenerative processes rather than solely inflammatory processes (Binks et al., 2015; McGonagle et al., 2009). Given that the presence of macro-porosity was seen in the same joint complex as the trauma, it is probable that a degenerative process was stimulated by the traumatic event. Further research timing EC presence in relation to antemortem injuries could clarify this association.

Enthesitis of the *quadriceps femoris* insertion is generally attributed to imbalanced forces of the muscles during the knee extension (Toumi et al., 2006), in which variations in tensile loads coming from the four different muscles are applied to specific points of the entheseal surface. The anatomy within the entheseal surface is also variable, since the amount and location of the fibrocartilage depends on the mechanical stimuli (Benjamin & Ralphs, 1998; Toumi et al., 2006, 2014). The *quadriceps femoris* has greater quantities of fibrocartilage in the central and lateral part of the surface demonstrating the effect of imbalanced loads over the enthesis anatomy (Toumi et al., 2014). Therefore, the exact location of the feature within the entheseal surface may help to understand their etiology. The current new Coimbra method differentiates the margin (zone 1) from the rest of the enthesis (zone 2) (Henderson et al., 2013, 2016; Henderson, Wilczak, et al., 2017). However, further divisions within zone 2 could be appropriate for anatomically complex entheses formed by two or more muscles such as the *quadriceps femoris* insertion and the *biceps brachii*.

On the other hand, the early stages of enthesitis seem to be asymptomatic (McGonagle, Marzo-Ortega, O’Connor, Gibbon, Hawkey, et al., 2002; Miller, 2007), which makes the presence of fine porosity in entheses of a given skeleton under forensic investigation impossible to match with physical discomfort manifested by the individual. Therefore, the usefulness of the presence of fine porosity for personal identification is low, unless compensatory movements are clearly established and are linked to previous injuries.

4.3.2. Second pattern

The second pattern that demonstrates the association between ECs and skeletal evidence of antemortem trauma refers to the presence of ECs in the same limb, but in a joint complex different from the injured one. This pattern is seen in three out of the nine associations (33%), one of which was in the upper limbs (Table 3-64), and the other two were in the lower limbs (Table 3-71). These were the presence of textural change in the right common flexor origin when the right shoulder exhibited trauma; presence of fine porosity in the left *quadriceps femoris* when the left hip was injured; and presence of fine porosity in the right patellar ligament when the right lower limb was injured, particularly in the hip. This pattern showed the highest effect size values of the three patterns and demonstrates the secondary effect of injures in the skeleton, namely compensatory movements.

This study found association with textural change in the right common flexor origin when the right shoulder exhibited trauma. Based on the fact that onset of medial epicondylitis has been mostly attributed to overuse injuries (Kijowski & De Smet, 2005) and the potential relationship between enthesis thickening and textural change, it is suggested that active or previous restrictions of shoulder movements were compensated through wrist movements causing an overuse injury in the elbow. However, the association between textural change and antemortem trauma found in this thesis was weak. Which, in addition to the high prevalence of enthesis thickening and hypoechogenicity in healthy individuals and individuals with different pathological conditions (Di Matteo et al., 2020; Falsetti et al., 2020), along with the lack of understanding of the etiology of textural change, make these skeletal features deficient evidence for the purposes of personal identification in forensic anthropology. Nevertheless, it is worth noting that while current knowledge is insufficient to include the presence of textural change as skeletal evidence in forensic investigations, further research could strengthen the use of these features to support skeletal identifiers, such as overuse injuries.

Skeletal evidence of antemortem injuries in the lower limbs, mostly in the hip, were associated with the presence of fine porosity in two different entheses, the insertion of the right patellar ligament and the insertion of the left *quadriceps femoris*. Both muscles are responsible for knee movements and stabilization of the patellar. In order to complete functional goals, weak or fatigued muscles cause reorganization of body movements (Côté et al., 2002). Such reorganizations can be seen through two strategies: a redistribution of the biomechanical loads to another joint, or changes in the muscle balance within the same joint (Bonnard et al., 1994; Côté et al., 2002). As previously discussed, inflammation in the *quadriceps femoris* is often associated with muscle imbalances (Toumi et al., 2006). Therefore, it is likely that compensatory movements occurred in both the left and the right knee after the upper leg was injured. As described in the first pattern, the presence of fine porosity could be associated with the invasion of blood vessels or vasodilatation during the early stage of entheseal repair (Benjamin et al., 2007; Schett et al., 2017).

Injuries in the patellar ligament, known as jumper's knee, are often incurred by male individuals, between 30 and 40 years of age and linked to overuse injuries or overload activities involving knee flexion such as running and jumping (Hsu & Siwiec, 2020). Most of the lesions are reported in the proximal area of the patellar ligament, while injuries near the tibial tuberosity are rare (Sarimo et al., 2007). Kulig et al. (2013) found that elite volleyball players had thicker entheses compared to the non-athletes. But most of the elite volleyball players with knee pain had lesions in the origin of the patellar ligament rather than at the insertion, and all of them had greater collagen bundle disorganization than both the asymptomatic elite volleyball players and the non-athletes. Kulig and colleagues concluded that such disorganization evidences a degeneration process rather than an exclusively inflammatory process, which in turn, causes painful symptoms. The etiology of such degenerative processes is not fully understood, but it is suggested that high tensile forces may be playing a significant role (Hsu & Siwiec, 2020; Kulig et al., 2013). However, fine porosity is likely to be part of the initial inflammatory response that appears to be mainly asymptomatic.

This study found a weak association between antemortem injuries in the hip area, with presence of fine porosity in the *quadriceps femoris* and the tibial tuberosity of the same side. Considering the location of the lesion and the suggested origin of fine porosity, it is proposed that lesions in the upper leg increase the load of the knee flexion movements and stabilization of the patellar, which inflames the enthesis and, in turn, initiates its healing response process. *Quadriceps femoris* is a common site of injury affecting nearly 1.3% of the United States population each year, but distal patellar tendinitis affects less than 0.5% of the population in the same country (Hsu & Siwiec, 2020). The low prevalence of the distal patellar tendinitis can be useful for personal identification if skeletal features are consistent with the lesion *in vivo*. Unfortunately, the association between fine porosity in the tibial tuberosity when antemortem lesions were seen in the hip is weak, and presence of fine porosity may be asymptomatic, reducing the usefulness of this feature in the forensic analysis.

Considering that the presence of fine porosity was also associated with antemortem lesions in the same joint complex in the first pattern, the mechanism of the association of antemortem trauma and porosities remains ambiguous. It can be related to overload of weakened muscle as proposed in the first pattern, or overload resulting from compensatory muscles as proposed in the second pattern. Nevertheless, it is unclear if pain was present during the vasodilatation phase, making it difficult to associate entheseal changes with antemortem data.

4.3.3. Third pattern

The third pattern is characterized by the presence of entheseal changes when the opposite limb was injured and can be read as further evidence of compensatory movements. This pattern emerged with three out of nine associations found (33%): the presence of textural change in the right *subscapularis* when the left shoulder was injured, presence of fine porosity in the right *subscapularis* when the left elbow was injured, and presence of erosion in zone 1 in the right *supraspinatus* when the left elbow and/or hand were injured. It is worth noting that this pattern was observed only in the upper limbs and associated with ECs in two entheses of the right rotator cuff when the opposite limb was injured. The right arm is the dominant limb of the majority of male individuals in Colombia (average of 90.5%) (Ardila & Rosselli, 2001), which makes adaptive movements more easily accepted by this arm. Studies performed in elite athletes showed that dominant limbs are stronger than the non-dominant limbs, but also are prone to overuse injuries (Notarnicola et al., 2014; H. K. Wang et al., 2000; H. K. Wang & Cochrane, 2001). Moreover, compensatory movements can occur with the mere presence of pain, when no massive damage is involved (Smeulders et al., 2001). Therefore, it is likely that lesions on the left arm contribute to overuse injuries in the right shoulder (Carey et al., 2008; Østlie et al., 2011; S. Wang et al., 2018).

The etiology of textural change and fine porosity has been discussed in the two previous patterns. Textural change could be associated with entheseal thickening or hypoechogenicity in active or past inflammatory processes and early stages of degenerative processes, while fine porosity seems related to normal vascularization of the enthesis responding to biomechanical, or inflammatory stressors. None of the soft-tissue lesions that could be associated with textural change or fine porosity appear to be symptomatic (Di Matteo, Filippucci, Cipolletta, Martire, et al., 2018; McGonagle, Marzo-Ortega, O'Connor, Gibbon, Hawkey, et al., 2002).

Subscapularis origin tears are rare, with an incidence ranging from 4% to 8% (Flury et al., 2006), often attributed to degenerative processes observed in individuals older than 50 years, and less commonly the consequence of acute trauma in younger individuals (Deutsch et al., 1997). Age was neither significant for fine porosity nor textural change in the right shoulder (Table 3-16). The presence of fine porosity in the right *subscapularis* was significant when both the left and the right elbow were injured, but the association on the right side ceased to be significant after the Bonferroni correction. Therefore, fine porosity in the rotator cuff may indicate that biomechanical loads are often focused on the right shoulder, but they increase when the left arm is unable to fully support the individual's normal loads. Considering that the probable etiology of both textural change and fine porosity has high prevalence on asymptomatic individuals, the forensic use of these two entheseal changes is quite limited.

The results also indicated association between the presence of erosion in zone 1 in the right *supraspinatus* and the left elbow or wrist/hand injuries. This association can suggest that daily movements of the left forearm and hand were compensated by movements of the opposite shoulder (Bonnard et al., 1994), which is likely to be their dominant arm (Ardila & Rosselli, 2001). It is also likely that overload of the shoulder altered normal reparative processes of the rotator cuff entheses, which triggered failures in the self-healing process that resulted in the presence of calcium crystals adjacent to the bone cortex i.e. calcifying tendinitis with bone involvement (Sansone et al., 2018). Moreover, the enthesis of the *supraspinatus* insertion has been involved in 77% of the calcifications showing cortical lesions (Porcellini et al., 2009), and associated with shoulder pain in almost all cases (Sansone et al., 2016). The origin of the erosions in zone 1 in the *supraspinatus* enthesis when antemortem lesions are present could be linked to calcium crystals in contact with the bone cortex rather than the effect of compressive forces (McGonagle et al., 2008) or bone marrow edema seen in early stages of enthesitis (Eriksen, 2015; Hayter et al., 2013; McQueen et al., 1999) which are the other two factors that have been associated with erosions in the entheseal surface. Nevertheless, the lack of medical records or antemortem evidence for this sample does not allow for the elimination of these other possible causes.

Erosions observed in dry bone have been associated with aging (Henderson, Mariotti, et al., 2017; Wilczak et al., 2019), along with other factors such as BMI and biomechanical overload. Three out of four individuals showing erosion in zone 1 when the opposite arm was injured had a mean age-at-death of 50 years, SD 2.9 years, and the fourth individual was older (61 years) but his right leg was amputated below the knee, which usually causes major alterations to body motions (Gambrell, 2008; Østlie et al., 2011). Therefore, middle adult individuals suffering injuries in the left arm may be prone to develop erosions in zone 1 in the right *supraspinatus* enthesis. Nevertheless, the association between EC and trauma was weak, and larger sample size are required to further explore this association in male individuals. Moreover, considering that calcifying tendinitis involving bone tissue has been associated with shoulder pain, and that the individual may have revealed the discomfort to family members or acquaintances, thus, the presence of erosions in the *supraspinatus* enthesis is worth further exploration as a potential anthropological identifier.

In summary, the three patterns discussed above suggest that the association between antemortem trauma and four different types of entheseal changes i.e. textural change, fine porosity, macro-porosity, and erosion in zone 1, found in this research demonstrates that trauma is one of the factors involved in the presence of EC. Skeletal consequences of the antemortem lesions can either stimulate inflammatory or degenerative processes in the impacted area, as seen in the first pattern, or cause alterations in the distributions of biomechanical loads, as explained in both the second and third pattern. The general right handedness of human populations helps to understand the movements of biomechanical loads from an injured section to another segment of the same right limb (Ayhan et al., 2014; Côté et al., 2002), as evidenced in the second pattern, or transferences to the opposite limb, i.e. the right side, as seen in the third pattern. Nevertheless, several confounding factors are involved in the consequences of antemortem lesions in the bone tissue such as the complex anatomy of the enthesis organ (Benjamin et al., 2004, 2006), differential turnover rate during maturation, and adulthood (Benjamin et al., 2007; Polachek et al., 2018; Schlecht, 2012; Skedros et al., 2007), as well as aging and BMI (Bakirci et al., 2020; Godde & Taylor, 2013; Henderson, Mariotti, et al., 2017) prevent the presence of any of the changes on the entheseal surface from being directly attributed to one exclusive factor. However, the relationship between erosion in zone 1 and antemortem lesions can be potentially useful as skeletal identifiers. Unfortunately, the current lack of understanding of the etiology of entheseal changes restricts the use of these skeletal features as sole indicators of antemortem trauma when assisting in personal identification.

4.4. Forensic impact

The Argentine Forensic Anthropology Team -EAAF (initials of *Equipo Argentino de Antropología Forense*) considers it essential to conduct forensic identifications in constant coordination with relatives (Salado & Fondebrider, 2008). Colombia has recently taken the same approach in which the search for remains includes greater involvement of relatives throughout the entire process (Díaz & Urueña, 2020). Family members are considered an active part of the investigation in which decisions are consulted, the processes and conclusions are explained to them, and more importantly, it is expected that the final results help them in their grief (Díaz & Urueña, 2020; López, 2020). Skeletal features of personal identification are strong physical evidence that relatives can see and understand to reassure them of the identification of the skeleton. For instance, when there is overlap between forensic anthropological recognition of skeletal evidence of antemortem injury and relatives' memories (who may remember the event or the recovery process), this may help the relative emotionally in feeling that they have recovered their missing loved one.

Skeletal identifiers are highly valuable in cases where blood relatives are found in the same forensic context, which is frequent in Colombia and other countries under armed conflicts (de Boer et al., 2020; Komar, 2003; Steadman et al., 2006). Komar and Lathrop (2006) found that two or more individuals can have similar evidence of fractures, pathologies, and surgical interventions and warned of the risks of making positive identifications based on morphological features alone. However, they demonstrate that a combination of skeletal features narrows down the possible matches to a few skeletons. Skeletal features indicating soft tissue lesions can contribute to further reducing the list, especially when the possible victims are known and limited by exhaustive previous investigation e.g., airplane accidents, or victims from a particular event (Ríos et al., 2010).

Moreover, antemortem trauma can be common in athletes or violent communities, but analyzing the exact location of the lesion in conjunction with age, sex and other factors, is useful for personal identification (Cappella et al., 2019). For instance, osteoarthrosis lesions are commonly found in older persons, while rarely found in young persons unless a traumatic lesion was present. Which, in turn, increases the uniqueness of this skeletal identifier if the feature can be matched with antemortem data. Likewise, bone formation is often associated with old individuals, but the presence of this type of EC in young individuals indicates that an additional stressor is playing a role.

One of the biggest challenges of inferring antemortem traumas from entheseal changes is to find consistent and solid antemortem information to compare with. As previously discussed, the rural side of Colombia has serious deficiencies in quality and coverage of institutional medical care, therefore it is unlikely that victims of the armed conflict have medical records or diagnostic images that can be used for forensic comparison. However, the lack of such medical care for musculoskeletal injuries means that these could be a potential target for new approaches in assessing the biological profile. Testimony is often the only antemortem record available, therefore, it is a priority to strengthen the trust of relatives in both the search process and the professionals involved. The antemortem format for lesions and physical activities must be detailed and complete, and faithful accounts from relatives is essential. For instance Rodriguez and Arango (2014) reported that two biological brothers were found in the same burial context and personal identification was based on a congenital disorder reported for one of the siblings as "*tenia los brazos torcidos, igual que uno de los brazos del padre*", meaning that "he had crooked arms, just like one of his father's arms" (p. 26). In this case a rare congenital disease was used to distinguish two biological brothers that otherwise would be very difficult to differentiate. Although this is a rare disease, critical information was obtained through testimonies and not medical records, which demonstrates that relatives can give powerful information in their testimony, especially in rural areas, and that pathological conditions and traumatic injuries are useful identifiers.

The forensic report must rely upon strong skeletal evidence to both contribute to personal identifications and to strengthen the scientific base of forensic anthropology. The results of this thesis found associations between antemortem lesions with the presence of EC with weak to medium effect size, which limits the use of EC as evidence of antemortem trauma. However, this research demonstrates that antemortem trauma is related to textural change, fine porosity, and erosions in entheses near the lesion site and other segments of the same limb or the opposite limb. These results aid in highlighting the complex relationship between soft tissue and bone tissue, and that entheses hold potentially useful information to personal identification regarding lesions, and diseases. This new data supports the request of forensic anthropology to recognize the value of skeletal identifiers when their uniqueness is fully demonstrated (Baraybar, 2008; de Boer et al., 2020), by indicating that in the absence of body segments or traditional skeletal features showing antemortem trauma e.g., fractures, myositis ossificans, certain types of entheseal changes can point to antemortem injuries.

5. CONCLUSIONS

This research sought to strengthen the contribution of forensic anthropology to personal identification by analyzing the relationship between entheseal changes and skeletal evidence of antemortem trauma and the usefulness of this relationship within the personal identification process in Colombian male individuals. Two secondary objectives were set to reach the main objective: the first was to determine the prevalence of EC in male individuals from two modern identified skeletal collections of Colombia; and to determine the relationship between EC and skeletal evidence of antemortem trauma in the same individuals.

Based on the analysis of EC presence in fibrocartilaginous entheses of male individuals from two skeletal collections, it can be concluded that antemortem trauma has a relationship with four out of the seven types of EC: fine porosity, textural change, macro-porosity, and erosion. Three different patterns of association were identified:

- EC in the same joint complex as the lesion.
- EC in a different joint complex than the lesion.
- EC in the opposite limb from where the lesion is located.

However, the strength of those relationships was medium at best, and several other factors such as age, sex hormones, BMI, and bone former diseases are also involved in the process, limiting the usefulness of EC as a direct predictor of antemortem trauma within the forensic analysis.

The results also demonstrate that the presence of EC can vary among populations due to factors that require further research. The analysis of the location and types of EC suggest that the difference of trends between the two collections could be related to different biomechanical loads and greater genetic predisposition to bone former diseases in individuals from Medellin. Population variability is influenced by genetic, environmental, social, and economic factors, amongst others, that affect the presence and characteristics of certain skeletal features. Some of those features, such as bone formation and porosity, are assessed in the entheseal surface of fibrocartilaginous entheses, but are also recorded in joint surfaces by some methods of age estimation. The results show that the presence of EC is not only related to aging, and that population variability must be considered as a factor in the analysis of macroscopic features in entheses and joint surfaces.

The results of this study indicate that injuries are related to changes in the entheseal surface but mostly in a different segment from where the lesion is seen, leading to the conclusion that the main effect of antemortem trauma is secondary and that weakened muscles or biomechanical imbalances may be the underlying factors of this association. This conclusion is supported by the fact that fine porosity is the feature showing the greatest association with antemortem trauma. Considering that porosities are associated with an initial reparative response, and that the EC is in a different segment than the lesion, it is likely that the presence of fine porosity is related to an onset of inflammatory processes triggered by biomechanical overloads. However, the medium strength of the relationship could be showing that additional anatomical and structural factors must be considered within the analysis such as the anatomy of each enthesis, the individual’s physiological limits, the nutritional status, and bone health. Whether the entheseal responses are temporary or permanent is still uncertain.

Considering that personal identification is a comparative process and that the current Colombian armed conflict limits the available antemortem information, it is both urgent and essential to improve personal identification methods based on bone tissue and to strengthen the relationship between relatives and forensic teams, which will allow more detailed testimonies to be obtained regarding localized pain or discomfort that will help to reach better results in the forensic anthropological analysis.

Forensic anthropologists have been developing statistical approaches for the quantification of skeletal non-metric features to reduce the subjectivity of the assessment of morphological characteristics. The vast variability of human bones poses a challenge to these efforts, thereby prompting in-depth analysis of skeletal evidence. If we consider the human body as a temporal unit that reflects the biological history of the individual, human variability should be considered amongst the strengths of forensic anthropology, rather than a weakness. Similarly, all changes observed in the entheseal surface offer valuable evidence of active or previous inflammation, early signs of rheumatic diseases, or biomechanical overloads that can strengthen the forensic analysis when analyzed together with other skeletal evidence that takes into consideration developmental history and biological profile at death.

The forensic standards require high accuracy and repeatability of a certain method to be admissible in the courtroom, and, while recording repeatability does meet forensic requirements, the results of this study do not reach the requirements to use EC patterns to identify trauma. Accordingly, entheseal changes cannot be used as unique evidence to predict antemortem trauma within the forensic context. Repeatability of the method used is a requirement for admissibility of scientific evidence in the courtroom (Christensen & Crowder, 2009). The new Coimbra method is a new record system that assesses each of the changes independently, and as with any other non-metric method, requires training before applying it (Henderson et al., 2016). Studies on repeatability of methods assessing morphological features have concluded that experience of the rater increases repeatability, while the ability to spot subtle changes and different interpretations of the descriptions decrease repeatability (C. B. Davis et al., 2013; Klales et al., 2012; Wilczak et al., 2017). Jorgensen and colleagues (2020) concluded that the Coimbra method was not yet reliable enough to be widely applied for scoring EC in fibrocartilaginous entheses, but the intra-rater error of the same study evidenced a substantial agreement. Therefore, descriptions of the method appear to be clear enough for a constant score of EC. Moreover, some entheses showed more reliable results than others, which suggest that anatomical variability is a limitation when assessing EC but should not be considered an error of the Coimbra method. Therefore, better understanding of each enthesis is needed prior to scoring EC, this is, the observer must be able to clearly delimit the entire enthesis surface, and to recognize the more frequent morphological variations.

5.1. Limitations

- One of the main limitations of this study was the size of the samples and lack of detailed information about antemortem injuries. The analysis was performed with small sample size of individuals showing lesions in each of the joint complexes, especially lesions indicating soft tissue injuries.
- Antemortem records do not provide information about lesions including timing, severity, and location, and complaints of pain or discomfort during the last year of the individual's

life. Such lack of information limited both the accuracy of the interpretations of the results and the symptoms that can be matched with skeletal features.

- As reported in other studies of EC, this research had limitations of obtaining complete records of biomechanical loads such as main occupation at death, labor history, intensity, and time of playing sports, and history of physical activity. This limited the analysis of the individual's physiological limits.
- Another limitation is that only male individuals were analyzed. It is important to note that although young male individuals are the most relevant population for forensic research in Colombia, there are changes in the prevalence of tendinopathies depending on sex. Therefore, it is relevant to test whether these results are different in females.
- Sonographers have found that BMI has a relationship with changes within tendons and entheseal surfaces, and the lack of BMI estimates limits the results of this study. However, current regression formulae to calculate body mass in skeletal material were developed in white populations. Therefore, the use of such regressions without adjustments can introduce an additional bias to this sample of male Colombians, which are mostly a non-white population.
- The anatomical variability of the entheseal surface can affect the assessment of EC, but this limitation is reduced by recognizing the scope of normal variability of each enthesis.

5.2. Future research

- Further studies with larger sample size can improve the understanding of the relationship between EC and antemortem trauma by recognizing if other factors such as BMI, sex, biomechanical loads, bone health, and physiological limits can affect the strength of that relationship.
- Another important question is the timing of entheseal changes in relation to antemortem trauma. Whether the changes in the entheseal surface appear as part of the healing process or several months later will strengthen the relationship between them, and in turn, the usefulness of EC as predictors of antemortem trauma.
- This study highlighted the fact that terrain altitude, rather than type of terrain i.e., flat, or rugged, can be associated with EC trends. Further study of presence of EC in different

altitudes in which the blood oxygen levels differ can clarify the terrain conditions required to cause differences in EC frequency.

- Several regression formulae for skeletal material such as BMI were developed in skeletal collections that hosted mostly white populations. Therefore, future research will benefit if all the formulae used in the Colombian forensic context are adjusted or developed using national skeletal collections.
- The results of this research suggested that the high presence of bone formation in young and middle adults from the UdeA collection may be related to an early onset of bone former diseases such as ankylosis spondylitis. However, the inclusion criteria of this dissertation excluded all individuals showing skeletal signs of such diseases, most of whom were older than 50 years. Further research including all age groups and clinical records could help to confirm whether the presence of bone formation in younger individuals is related to pathological factors.
- Factors linked to quality of life such as poor or undernutrition has been proven to have an effect on bone growth and development. A future research direction could be to study the impact of poor nutrition on muscle development and strength, which in turn, may alter the enthesis.
- The anatomy of some complex entheses involving two or more muscles can be highly variable. Therefore, it would be interesting to analyze the ECs taking into account the exact location within the entheseal surface. Further studies will clarify the implications of each entheseal change, not only in relation to the change itself, but also in relation to the localization inside the enthesis and the associated soft tissue, i.e., a mineralized tissue formation type of change may evidence a different situation if found on the Achilles tendon rather than *biceps brachii.*
- Systematic reports of muscle injuries within each forensic context will allow an estimate of prevalence by sex and age, which in turn will enable the uniqueness of the anthropological identifiers to be calculated.

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Appendices

Appendix 1. Survey of trauma and activity-related antemortem data

Formulario de recolección de datos antemortem relacionado con las actividades y los traumas -DARAT

Fecha ________ Caso # ________ Formulario # ________

Su relación con el fallecido ________ Tiempo de relación ________

Información del fallecido: Ocupación principal ________

Otras ocupaciones ________ Zurdo ☐ Diestro ☐ No sabe ☐

Durante la ocupación principal pasaba más del 50% de la jornada laboral:

Sentado ☐ Parado ☐ Caminando ☐ Arrodillado ☐ No sabe ☐

El trabajo involucraba cargar peso?

Menos que 1 kg	☐	Entre 10 -15 kg	☐	Ninguno	☐
Entre 5 -10 kg	☐	Mas de 15 kg	☐	No sabe	☐

Si cargaba cosas, cuantas horas por dia?

Entre 0-1 hora ☐ Entre 3-5 horas ☐ Entre 1-3 horas ☐ Mas de 5 horas ☐

Hace cuanto estaba realizando ese trabajo?

Entre 0-6 meses	☐	Entre 1 - 2 años	☐	Entre 5-10 años	☐	No sabe	☐
Entre 6-12 meses	☐	entre 2-5 años	☐	Mas de 10 años	☐		

Medio de transporte regular

Carro particular/taxi	☐	Transmilenio/bus	☐	A pie	☐
Bicicleta	☐	Moto	☐	Otro, cual?	________

Cuanto tiempo caminaba a la semana (transporte, trabajo o ejercicio)

Entre 5-30 min	☐	Entre 1-2 horas	☐	Mas de 3 horas	☐
Entre 30 min-1 hora	☐	Entre 2-3 horas	☐	No sabe	☐

Cuanto tiempo a la semana hacia otra actividad física

Dias por semana ________ Horas por dia ________

Durante su infancia y/o adolescencia practicó algun deporte

Cual? ________

Intensidad: Fines de semana ☐ Entrenamiento diario ☐
Entrenamiento semanal ☐ Ocasional (1-2/mes) ☐ No sabe ☐

En los ultimos 10 años practicó algun deporte?
Si ☐ No ☐ No sabe ☐ Cual? ____________________

En los ultimos 5 años practicó algun deporte?
Si ☐ No ☐ No sabe ☐ Cual? ____________________

En el ultimo años practicó algun deporte?
Si ☐ No ☐ No sabe ☐ Cual? ____________________

Cuanto tiempo a la semana veia televisión o navegaba en internet
Dias por semana __________ Horas por dia __________

Fracturas Si ☐ No ☐ No sabe ☐
En que parte del cuerpo? ____________________
Lesiones musculares Si ☐ No ☐ No sabe ☐
En que parte del cuerpo? ____________________
Se quejaba de dolor Si ☐ No ☐ No sabe ☐
En que parte del cuerpo? ____________________
Comentario: ____________________

Appendix 2. Frequencies of score 1 and score 2 in the entheses in the upper limbs of the UdeA collection. Total sample 69 individuals.

			BF (Z1)		ER (Z1)		TC		BF (Z2)		ER (Z2)		FPO		MPO		CA	
Enthesis	**Side**	**Score**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**
Subscapularis	Right	0	43	62.3	60	87	61	88.4	47	68.1	48	69.6	63	91.3	62	89.9	65	94.2
		1	21	30.4	4	5.8	6	8.7	20	29	15	21.7	4	5.8	5	7.2	1	1.4
		2	1	1.4	1	1.4	-	-	0	0	4	5.8	0	0	0	0	1	1.4
		NR	4	5.8	4	5.8	2	2.9	2	2.9	2	2.9	2	2.9	2	2.9	2	2.9
	Left	0	49	71	56	81.2	59	85.5	51	73.9	55	79.7	64	92.8	65	94.2	65	94.2
		1	12	17.4	4	5.8	7	10.1	15	21.7	11	15.9	3	4.3	2	2.9	2	2.9
		2	0	0	1	1.4	-	-	0	0	1	1.4	0	0	0	0	0	0
		NR	8	11.6	8	11.6	3	4.3	3	4.3	2	2.9	2	2.9	2	2.9	2	2.9
Supraspinatus	Right	0	54	78.3	55	79.7	56	81.2	56	81.2	55	79.7	60	87	59	85.5	61	88.4
		1	2	2.9	1	1.4	6	8.7	6	8.7	6	8.7	2	2.9	3	4.3	0	0
		2	0	0	0	0	-	-	0	0	1	1.4	0	0	0	0	1	1.4
		NR	13	18.8	13	18.8	7	10.1	7	10.1	7	10.1	7	10.1	7	10.1	7	10.1
	Left	0	52	75.4	51	73.9	54	78.3	60	87	55	79.7	57	82.6	60	87	61	88.4
		1	3	4.3	4	5.8	7	10.1	1	1.4	5	7.2	4	5.8	1	1.4	0	0
		2	0	0	0	0	-	-	0	0	1	1.4	0	0	0	0	0	0
		NR	14	20.3	14	20.3	8	11.6	8	11.6	8	11.6	8	11.6	8	11.6	8	11.6
Infraspinatus	Right	0	53	76.8	53	76.8	49	71	49	71	50	72.5	51	73.9	53	76.8	56	81.2
		1	1	1.4	0	0	7	10.1	7	10.1	6	8.7	5	7.2	3	4.3	0	0
		2	0	0	1	1.4	-	-	0	0	0	0	0	0	0	0	0	0
		NR	15	21.7	15	21.7	13	18.8	13	18.8	13	18.8	13	18.8	13	18.8	13	18.8
	Left	0	51	73.9	51	73.9	48	69.6	47	68.1	46	66.7	49	71	51	73.9	52	75.4
		1	0	0	0	0	4	5.8	5	7.2	6	8.7	3	4.3	1	1.4	0	0
		2	0	0	0	0	-	-	0	0	0	0	0	0	0	0	0	0
		NR	18	26.1	18	26.1	17	24.6	17	24.6	17	24.6	17	24.6	17	24.6	17	24.6
Common extensor	Right	0	38	55.1	58	84.1	61	88.4	50	72.5	55	79.7	63	91.3	62	89.9	63	91.3
		1	17	24.6	0	0	2	2.9	13	18.8	8	11.6	0	0	1	1.4	0	0
		2	3	4.3	0	0	-	-	0	0	0	0	0	0	0	0	0	0
		NR	11	15.9	11	15.9	6	8.7	6	8.7	6	8.7	6	8.7	6	8.7	6	8.7
	Left	0	37	53.6	50	72.5	51	73.9	45	65.2	47	68.1	52	75.4	52	75.4	53	76.8
		1	12	17.4	0	0	2	2.9	8	11.6	6	8.7	1	1.4	1	1.4	0	0
		2	1	1.4	0	0	-	-	0	0	0	0	0	0	0	0	0	0
		NR	19	27.5	19	27.5	16	23.2	16	23.2	16	23.2	16	23.2	16	23.2	16	23.2
Common flexor	Right	0	48	69.6	57	82.6	56	81.2	45	65.2	52	75.4	54	78.3	56	81.2	57	82.6
		1	9	13	0	0	1	1.4	12	17.4	5	7.2	3	4.3	1	1.4	0	0
		2	0	0	0	0	-	-	0	0	0	0	0	0	0	0	0	0
		NR	12	17.4	12	17.4	12	17.4	12	17.4	12	17.4	12	17.4	12	17.4	12	17.4

	Left	0	46	66.7	52	75.4	50	72.5	48	69.6	44	63.8	52	75.4	52	75.4	52	75.4
		1	7	10.1	1	1.4	2	2.9	4	5.8	7	10.1	0	0	0	0	0	0
		2	0	0	0	0	-	-	0	0	1	1.4	0	0	0	0	0	0
		NR	16	23.2	16	23.2	17	24.6	17	24.6	17	24.6	17	24.6	17	24.6	17	24.6
Biceps brachii	Right	0	21	30.4	53	76.8	36	52.2	43	62.3	43	62.3	66	95.7	65	94.2	67	97.1
		1	33	47.8	11	15.9	31	44.9	23	33.3	19	27.5	1	1.4	2	2.9	0	0
		2	10	14.5	0	0	-	-	1	1.4	5	7.2	0	0	0	0	0	0
		NR	5	7.2	5	7.2	2	2.9	2	2.9	2	2.9	2	2.9	2	2.9	2	2.9
	Left	0	16	23.2	55	79.7	25	36.2	47	68.1	45	65.2	64	92.8	64	92.8	65	94.2
		1	40	58	8	11.6	41	59.4	17	24.6	18	26.1	2	2.9	2	2.9	1	1.4
		2	7	10.1	0	0	-	-	2	2.9	3	4.3	0	0	0	0	0	0
		NR	6	8.7	6	8.7	3	4.3	3	4.3	3	4.3	3	4.3	3	4.3	3	4.3
Triceps brachii	Right	0	28	40.6	52	75.4	48	69.6	47	68.1	38	55.1	54	78.3	54	78.3	56	81.2
		1	21	30.4	1	1.4	8	11.6	8	11.6	18	26.1	2	2.9	2	2.9	0	0
		2	4	5.8	0	0	-	-	1	1.4	0	0	0	0	0	0	0	0
		NR	16	23.2	16	23.2	13	18.8	13	18.8	13	18.8	13	18.8	13	18.8	13	18.8
	Left	0	35	50.7	56	81.2	47	68.1	43	62.3	44	63.8	56	81.2	53	76.8	58	84.1
		1	18	26.1	0	0	11	15.9	14	20.3	14	20.3	2	2.9	5	7.2	0	0
		2	3	4.3	0	0	0	0	1	1.4	0	0	0	0	0	0	0	0
		NR	13	18.8	13	18.8	11	15.9	11	15.9	11	15.9	11	15.9	11	15.9	11	15.9

f= frequency, NR= not recordable, BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.

Appendix 3. Frequencies of EC presence within each age range. Upper limbs entheses of the UdeA skeletal collection.

		Age	BF (Z2)			ER (Z1)			TC			BF (Z2)			ER (Z2)			FPO			MPO			CA		
Side	**Enthesis**	**range**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**
Left	*Biceps brachii*	20-35	33	21	64%	33	5	15%	35	23	66%	35	11	31%	35	6	17%	35	1	3%	35	0	0%	35	0	0%
		36-50	17	13	76%	17	1	6%	18	13	72%	18	4	22%	18	9	50%	18	1	6%	18	0	0%	18	0	0%
		50-68	13	13	100%	13	2	15%	13	5	38%	13	4	31%	13	6	46%	13	0	0%	13	2	15%	13	1	8%
	Common extensor	20-35	27	2	7%	27	0	0%	28	1	4%	28	1	4%	28	1	4%	28	1	4%	28	1	4%	28	0	0%
		36-50	12	4	33%	12	0	0%	13	1	8%	13	1	8%	13	1	8%	13	0	0%	13	0	0%	13	0	0%
		50-68	11	7	64%	11	0	0%	12	0	0%	12	6	50%	12	4	33%	12	0	0%	12	0	0%	12	0	0%
	Common flexor	20-35	29	1	3%	29	1	3%	28	0	0%	28	0	0%	28	1	4%	28	0	0%	28	0	0%	28	0	0%
		36-50	12	1	8%	12	0	0%	12	1	8%	12	1	8%	12	3	25%	12	0	0%	12	0	0%	13	0	0%
		50-68	12	5	42%	12	0	0%	12	1	8%	12	3	25%	12	4	33%	12	0	0%	12	0	0%	11	0	0%
	Infraspinatus	20-35	26	0	0%	26	0	0%	26	2	8%	26	1	4%	26	1	4%	26	2	8%	26	0	0%	26	0	0%
		36-50	13	0	0%	13	0	0%	14	1	7%	14	1	7%	14	3	21%	14	1	7%	14	0	0%	14	0	0%
		50-68	12	0	0%	12	0	0%	12	1	8%	12	3	25%	12	2	17%	12	0	0%	12	1	8%	12	0	0%
	Subscapularis	20-35	30	2	7%	30	1	3%	33	4	12%	33	1	3%	34	4	12%	34	2	6%	34	0	0%	34	0	0%
		36-50	17	4	24%	17	1	6%	18	1	6%	18	6	33%	18	3	17%	18	1	6%	18	1	6%	18	1	6%
		51-68	14	6	43%	14	3	21%	15	2	13%	15	8	53%	15	5	33%	15	0	0%	15	1	7%	15	1	7%
	Supraspinatus	20-35	29	0	0%	29	0	0%	32	4	13%	32	0	0%	32	0	0%	32	2	6%	32	0	0%	32	0	0%
		36-50	13	0	0%	13	0	0%	15	1	7%	15	0	0%	15	1	7%	15	1	7%	15	0	0%	15	0	0%
		51-68	13	3	23%	13	4	31%	14	2	14%	14	1	7%	14	5	36%	14	1	7%	14	1	7%	14	0	0%
	Triceps brachii	20-35	30	6	20%	30	0	0%	30	4	13%	30	5	17%	30	8	27%	30	2	7%	30	2	7%	30	0	0%
		36-50	14	11	79%	14	0	0%	16	6	38%	16	4	25%	16	2	13%	16	0	0%	16	3	19%	16	0	0%
		51-68	12	4	33%	12	0	0%	12	1	8%	12	6	50%	12	4	33%	12	0	0%	12	0	0%	12	0	0%
	Total	20-35	204	32	16%	204	7	3%	212	38	18%	212	19	9%	213	21	10%	213	10	5%	213	3	1%	213	0	0%
		36-50	98	33	34%	98	2	2%	106	24	23%	106	17	16%	106	22	21%	106	4	4%	106	4	4%	107	1	1%
		51-68	87	38	44%	87	9	10%	90	12	13%	90	31	34%	90	30	33%	90	1	1%	90	5	6%	89	2	2%
Right	*Biceps brachii*	20-35	31	15	48%	31	7	23%	33	17	52%	33	12	36%	33	9	27%	33	0	0%	33	1	3%	33	0	0%
		36-50	18	16	89%	18	2	11%	19	10	53%	19	7	37%	19	5	26%	19	1	5%	19	0	0%	19	0	0%
		51-68	15	12	80%	15	2	13%	15	4	27%	15	5	33%	15	10	67%	15	0	0%	15	1	7%	15	0	0%
	Common extensor	20-35	30	3	10%	30	0	0%	32	0	0%	32	1	3%	32	0	0%	32	0	0%	32	0	0%	32	0	0%
		36-50	15	8	53%	15	0	0%	17	1	6%	17	6	35%	17	3	18%	17	0	0%	17	1	6%	17	0	0%
		51-68	13	9	69%	13	0	0%	14	1	7%	14	6	43%	14	5	36%	14	0	0%	14	0	0%	14	0	0%
	Common flexor	20-35	31	3	10%	31	0	0%	30	0	0%	30	4	13%	30	0	0%	30	2	7%	30	1	3%	30	0	0%
		36-50	14	3	21%	14	0	0%	14	0	0%	14	4	29%	14	1	7%	14	0	0%	14	0	0%	14	0	0%
		51-68	12	3	25%	12	0	0%	13	1	8%	13	4	31%	13	4	31%	13	1	8%	13	0	0%	13	0	0%
	Infraspinatus	20-35	26	0	0%	26	0	0%	27	3	11%	27	2	7%	27	2	7%	27	2	7%	27	1	4%	27	0	0%
		36-50	14	0	0%	14	0	0%	15	2	13%	15	2	13%	15	2	13%	15	1	7%	15	0	0%	15	0	0%

	51-68	14	1	7%	14	0	0%	14	2	14%	14	3	21%	14	2	14%	14	2	14%	14	2	14%	14	0	0%
Subscapularis	20-35	32	2	6%	32	0	0%	34	3	9%	34	3	9%	34	5	15%	34	2	6%	34	0	0%	34	0	0%
	36-50	18	9	50%	18	2	11%	18	2	11%	18	9	50%	18	7	39%	18	2	11%	18	2	11%	18	1	6%
	51-68	15	11	73%	15	3	20%	15	1	7%	15	8	53%	15	7	47%	15	0	0%	15	3	20%	15	1	7%
Supraspinatus	20-35	28	0	0%	28	0	0%	32	5	16%	32	1	3%	32	1	3%	32	1	3%	32	0	0%	32	0	0%
	36-50	14	0	0%	14	0	0%	16	1	6%	16	3	19%	16	2	13%	16	0	0%	16	0	0%	16	0	0%
	51-68	14	2	14%	14	1	7%	14	0	0%	14	2	14%	14	4	29%	14	1	7%	14	3	21%	14	1	7%
Triceps brachii	20-35	27	4	15%	27	0	0%	28	2	7%	28	4	14%	28	4	14%	28	1	4%	28	1	4%	28	0	0%
	36-50	14	12	86%	14	1	7%	15	3	20%	15	2	13%	15	8	53%	15	1	7%	15	0	0%	15	0	0%
	51-68	12	9	75%	12	0	0%	13	3	23%	13	3	23%	13	6	46%	13	0	0%	13	1	8%	13	0	0%
Total	20-35	205	27	13%	205	7	3%	216	30	14%	216	27	13%	216	21	10%	216	8	4%	216	4	2%	216	0	0%
	36-50	107	48	45%	107	5	5%	114	19	17%	114	33	29%	114	28	25%	114	5	4%	114	3	3%	114	1	1%
	51-68	95	47	49%	95	6	6%	98	12	12%	98	31	32%	98	38	39%	98	4	4%	98	10	10%	98	2	2%

f= frequency, BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.

Appendix 4. General frequencies of score 1 and 2 in the entheses in the upper limbs of the NILMFS collection. Total sample size 102 individuals.

			BF (Z1)		**ER (Z1)**		**TC**		**BF (Z2)**		**ER (Z2)**		**FPO**		**MPO**		**CA**	
Enthesis	**Side**	**Score**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**
Subscapularis	Right	0	62	60.8	87	85.3	94	92.2	58	56.9	61	59.8	88	86.3	85	83.3	91	89.2
		1	31	30.4	8	7.8	5	4.9	40	39.2	30	29.4	10	9.8	13	12.7	8	7.8
		2	5	4.9	3	2.9	-	-	1	1	8	7.8	1	1	1	1	0	0
		NR	4	3.9	4	3.9	3	2.9	3	2.9	3	2.9	3	2.9	3	2.9	3	2.9
	Left	0	66	64.7	82	80.4	89	87.3	62	60.8	74	72.5	86	84.3	87	85.3	90	88.2
		1	28	27.5	15	14.7	10	9.8	37	36.3	21	20.6	13	12.7	10	9.8	9	8.8
		2	6	5.9	3	2.9	-	-	0	0	4	3.9	0	0	2	2	0	0
		NR	2	2	2	2	3	2.9	3	2.9	3	2.9	3	2.9	3	2.9	3	2.9
Supraspinatus	Right	0	79	77.5	91	89.2	85	83.3	82	80.4	80	78.4	80	78.4	89	87.3	92	90.2
		1	13	12.7	2	2	10	9.8	12	11.8	7	6.9	15	14.7	4	3.9	3	2.9
		2	2	2	1	1	-	-	1	1	8	7.8	0	0	2	2	0	0
		NR	8	7.8	8	7.8	7	6.9	7	6.9	7	6.9	7	6.9	7	6.9	7	6.9
	Left	0	88	86.3	86	84.3	87	85.3	84	82.4	82	80.4	81	79.4	92	90.2	95	93.1
		1	5	4.9	6	5.9	9	8.8	11	10.8	7	6.9	13	12.7	3	2.9	1	1
		2	1	1	2	2	-	-	1	1	7	6.9	2	2	1	1	0	0
		NR	8	7.8	8	7.8	6	5.9	6	5.9	6	5.9	6	5.9	6	5.9	6	5.9
Infraspinatus	Right	0	87	85.3	93	91.2	89	87.3	79	77.5	76	74.5	89	87.3	92	90.2	92	90.2
		1	6	5.9	1	1	7	6.9	16	15.7	18	17.6	7	6.9	3	2.9	4	3.9
		2	1	1	0	0	-	-	1	1	2	2	0	0	1	1	0	0
		NR	8	7.8	8	7.8	6	5.9	6	5.9	6	5.9	6	5.9	6	5.9	6	5.9
	Left	0	88	86.3	92	90.2	86	84.3	72	70.6	78	76.5	80	78.4	92	90.2	90	88.2
		1	5	4.9	0	0	8	7.8	22	21.6	15	14.7	14	13.7	2	2	3	2.9
		2	0	0	1	1	-	-	0	0	1	1	0	0	0	0	1	1
		NR	9	8.8	9	8.8	8	7.8	8	7.8	8	7.8	8	7.8	8	7.8	8	7.8
Common extensor	Right	0	59	57.8	85	83.3	78	76.5	64	62.7	71	69.6	75	73.5	82	80.4	89	87.3
		1	21	20.6	3	2.9	12	11.8	26	25.5	19	18.6	15	14.7	8	7.8	1	1
		2	9	8.8	1	1	-	-	0	0	0	0	0	0	0	0	0	0
		NR	13	12.7	13	12.7	12	11.8	12	11.8	12	11.8	12	11.8	12	11.8	12	11.8
	Left	0	64	62.7	91	89.2	82	80.4	63	61.8	78	76.5	86	84.3	90	88.2	93	91.2
		1	26	25.5	3	2.9	11	10.8	30	29.4	15	14.7	7	6.9	3	2.9	0	0
		2	4	3.9	0	0	-	-	0	0	0	0	0	0	0	0	0	0
		NR	8	7.8	8	7.8	9	8.8	9	8.8	9	8.8	9	8.8	9	8.8	9	8.8
Common flexor	Right	0	61	59.8	78	76.5	78	76.5	62	60.8	60	58.8	72	70.6	81	79.4	81	79.4
		1	18	17.6	1	1	3	2.9	18	17.6	21	20.6	9	8.8	0	0	0	0
		2	0	0	0	0	-	-	1	1	0	0	0	0	0	0	0	0
		NR	23	22.5	23	22.5	21	20.6	21	20.6	21	20.6	21	20.6	21	20.6	21	20.6
	Left	0	64	62.7	80	78.4	87	85.3	66	64.7	70	68.6	83	81.4	86	84.3	88	86.3
		1	19	18.6	3	2.9	1	1	22	21.6	18	17.6	5	4.9	2	2	0	0
		2	0	0	0	0	-	-	0	0	0	0	0	0	0	0	0	0
		NR	19	18.6	19	18.6	14	13.7	14	13.7	14	13.7	14	13.7	14	13.7	14	13.7
Biceps brachii	Right	0	27	26.5	89	87.3	31	30.4	80	78.4	82	80.4	91	89.2	95	93.1	96	94.1
		1	61	59.8	10	9.8	67	65.7	18	17.6	14	13.7	7	6.9	3	2.9	2	2
		2	11	10.8	0	0	-	-	0	0	2	2	0	0	0	0	0	0
		NR	3	2.9	3	2.9	4	3.9	4	3.9	4	3.9	4	3.9	4	3.9	4	3.9
	Left	0	30	29.4	87	85.3	33	32.4	73	71.6	79	77.5	90	88.2	90	88.2	93	91.2
		1	56	54.9	10	9.8	62	60.8	22	21.6	15	14.7	5	4.9	5	4.9	2	2
		2	11	10.8	0	0	-	-	0	0	1	1	0	0	0	0	0	0
		NR	5	4.9	5	4.9	7	6.9	7	6.9	7	6.9	7	6.9	7	6.9	7	6.9
Triceps brachii	Right	0	38	37.3	80	78.4	75	73.5	73	71.6	70	68.6	84	82.4	90	88.2	91	89.2
		1	41	40.2	6	5.9	16	15.7	18	17.6	20	19.6	7	6.9	1	1	0	0
		2	7	6.9	0	0	-	-	0	0	1	1	0	0	0	0	0	0

	NR	16	15.7	16	15.7	11	10.8	11	10.8	11	10.8	11	10.8	11	10.8	11	10.8
Left	0	49	48	79	77.5	71	69.6	71	69.6	71	69.6	77	75.5	86	84.3	88	86.3
	1	32	31.4	5	4.9	17	16.7	17	16.7	16	15.7	11	10.8	2	2	0	0
	2	3	2.9	0	0	-	-	0	0	1	1	0	0	0	0	0	0
	NR	18	17.6	18	17.6	14	13.7	14	13.7	14	13.7	14	13.7	14	13.7	14	13.7

f= frequency, NR= No recordable, BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.

Appendix 5. Frequencies of EC by age range and side. Upper limbs, NILMFS skeletal collection. Total sample size 102 individuals

			BF (Z1)			**ER (Z1)**			**TC**			**BF (Z2)**			**ER (Z2)**			**FPO**			**MPO**			**CA**		
Side	**Enthesis**	**Age range**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**
Left	*Biceps brachii*	20-35	34	13	38%	34	5	15%	33	21	64%	33	5	15%	33	2	6%	33	1	3%	33	1	3%	33	0	0%
		36-50	33	25	76%	33	4	12%	33	22	67%	33	6	18%	33	5	15%	33	3	9%	33	0	0%	33	0	0%
		51-65	30	29	97%	30	1	3%	29	19	66%	29	11	38%	29	9	31%	29	1	3%	29	4	14%	29	2	7%
	Common extensor	20-35	33	3	9%	33	1	3%	32	2	6%	32	3	9%	32	4	13%	32	2	6%	32	1	3%	32	0	0%
		36-50	32	9	28%	32	0	0%	32	4	13%	32	11	34%	32	3	9%	32	2	6%	32	0	0%	32	0	0%
		51-65	29	18	62%	29	2	7%	29	5	17%	29	16	55%	29	8	28%	29	3	10%	29	2	7%	29	0	0%
	Common flexor	20-35	31	0	0%	31	1	3%	32	0	0%	32	1	3%	32	1	3%	32	0	0%	32	0	0%	32	0	0%
		36-50	29	5	17%	29	2	7%	30	1	3%	30	7	23%	30	4	13%	30	4	13%	30	1	3%	30	0	0%
		51-65	23	14	61%	23	0	0%	26	0	0%	26	14	54%	26	13	50%	26	1	4%	26	1	4%	26	0	0%
	Infraspinatus	20-35	34	0	0%	34	0	0%	34	1	3%	34	3	9%	34	1	3%	34	8	24%	34	0	0%	34	0	0%
		36-50	31	0	0%	31	0	0%	31	4	13%	31	9	29%	31	7	23%	31	5	16%	31	0	0%	31	2	6%
		51-65	28	5	18%	28	1	4%	29	3	10%	29	10	34%	29	8	28%	29	1	3%	29	2	7%	29	2	7%
	Subscapularis	20-35	35	3	9%	35	1	3%	34	5	15%	34	5	15%	34	3	9%	34	4	12%	34	0	0%	34	0	0%
		36-50	34	12	35%	34	4	12%	34	3	9%	34	11	32%	34	8	24%	34	4	12%	34	5	15%	34	4	12%
		51-65	31	19	61%	31	13	42%	31	2	6%	31	21	68%	31	14	45%	31	5	16%	31	7	23%	31	5	16%
	Supraspinatus	20-35	33	1	3%	33	0	0%	33	2	6%	33	0	0%	33	2	6%	33	3	9%	33	1	3%	33	0	0%
		36-50	32	1	3%	32	3	9%	33	3	9%	33	6	18%	33	7	21%	33	5	15%	33	1	3%	33	0	0%
		51-65	29	4	14%	29	5	17%	30	4	13%	30	6	20%	30	5	17%	30	7	23%	30	2	7%	30	1	3%
	Triceps brachii	20-35	29	3	10%	29	1	3%	32	3	9%	32	4	13%	32	5	16%	32	6	19%	32	1	3%	32	0	0%
		36-50	29	15	52%	29	3	10%	28	3	11%	28	7	25%	28	8	29%	28	3	11%	28	1	4%	28	0	0%
		51-65	26	17	65%	26	1	4%	28	11	39%	28	6	21%	28	4	14%	28	2	7%	28	0	0%	28	0	0%
	Total	20-35	229	23	10%	229	9	4%	230	34	15%	230	21	9%	230	18	8%	230	24	10%	230	4	2%	230	0	0%
		36-50	220	67	30%	220	16	7%	221	40	18%	221	57	26%	221	42	19%	221	26	12%	221	8	4%	221	6	3%
		51-65	196	106	54%	196	23	12%	202	44	22%	202	84	42%	202	61	30%	202	20	10%	202	18	9%	202	10	5%
Right	*Biceps brachii*	20-35	35	17	49%	35	2	6%	35	21	60%	35	4	11%	35	4	11%	35	1	3%	35	1	3%	35	0	0%
		36-50	33	28	85%	33	4	12%	33	26	79%	33	4	12%	33	4	12%	33	4	12%	33	0	0%	33	1	3%
		51-65	31	27	87%	31	4	13%	30	20	67%	30	10	33%	30	8	27%	30	2	7%	30	2	7%	30	1	3%
	Common extensor	20-35	32	0	0%	32	0	0%	32	3	9%	32	2	6%	32	3	9%	32	2	6%	32	1	3%	32	1	3%
		36-50	30	12	40%	30	2	7%	30	5	17%	30	9	30%	30	4	13%	30	5	17%	30	3	10%	30	0	0%
		51-65	27	18	67%	27	2	7%	28	4	14%	28	15	54%	28	12	43%	28	8	29%	28	4	14%	28	0	0%
	Common flexor	20-35	30	1	3%	30	0	0%	30	0	0%	30	4	13%	30	2	7%	30	1	3%	30	0	0%	30	0	0%
		36-50	27	5	19%	27	1	4%	27	1	4%	27	6	22%	27	7	26%	27	2	7%	27	0	0%	27	0	0%
		51-65	22	12	55%	22	0	0%	24	2	8%	24	9	38%	24	12	50%	24	6	25%	24	0	0%	24	0	0%
	Infraspinatus	20-35	34	0	0%	34	0	0%	34	2	6%	34	3	9%	34	1	3%	34	3	9%	34	0	0%	34	0	0%
		36-50	31	2	6%	31	0	0%	31	2	6%	31	2	6%	31	7	23%	31	0	0%	31	1	3%	31	2	6%

	51-65	29	5	17%	29	1	3%	31	3	10%	31	12	39%	31	12	39%	31	4	13%	31	3	10%	31	2	6%
Subscapularis	20-35	35	8	23%	35	0	0%	35	3	9%	35	5	14%	35	7	20%	35	3	9%	35	2	6%	35	2	6%
	36-50	32	12	38%	32	2	6%	33	1	3%	33	20	61%	33	13	39%	33	3	9%	33	6	18%	33	1	3%
	51-65	31	16	52%	31	9	29%	31	1	3%	31	16	52%	31	18	58%	31	5	16%	31	6	19%	31	5	16%
Supraspinatus	20-35	33	2	6%	33	0	0%	34	5	15%	34	1	3%	34	0	0%	34	4	12%	34	0	0%	34	0	0%
	36-50	32	4	13%	32	2	6%	32	2	6%	32	4	13%	32	6	19%	32	4	13%	32	2	6%	32	0	0%
	51-65	29	9	31%	29	1	3%	29	3	10%	29	8	28%	29	9	31%	29	7	24%	29	4	14%	29	3	10%
Triceps brachii	20-35	31	5	16%	31	0	0%	32	3	9%	32	2	6%	32	11	34%	32	3	9%	32	0	0%	32	0	0%
	36-50	28	19	68%	28	2	7%	31	5	16%	31	7	23%	31	5	16%	31	2	6%	31	1	3%	31	0	0%
	51-65	27	24	89%	27	4	15%	28	8	29%	28	9	32%	28	5	18%	28	2	7%	28	0	0%	28	0	0%
Total	20-35	230	33	14%	230	2	1%	232	37	16%	232	21	9%	232	28	12%	232	17	7%	232	4	2%	232	3	1%
	36-50	213	82	38%	213	13	6%	217	42	19%	217	52	24%	217	46	21%	217	20	9%	217	13	6%	217	4	2%
	51-65	196	111	57%	196	21	11%	201	41	20%	201	79	39%	201	76	38%	201	34	17%	201	19	9%	201	11	5%

f= frequency, BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.

Appendix 6. Asymmetry in the upper limbs by age range comparing the two skeletal collections.

			Overall				BF(Z1)				ER(Z1)				TC			
			NILMFS		UdeA		NILMFS		UdeA		NILMFS		UdeA		NILMFS		UdeA	
Enthesis	**Age range**	**Asymmetry**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**
Subscapularis	Young adult	Left side higher	10	27.8	4	11.4	6	17.6	0	0.0	0	0.0	0	0.0	1	3.0	2	6.3
		Equal	21	58.3	28	80.0	26	76.5	28	100.0	33	97.1	27	96.4	29	87.9	27	84.4
		Right side higher	5	13.9	3	8.6	2	5.9	0	0.0	1	2.9	1	3.6	3	9.1	3	9.4
		Total	36		35		34		28		34		28		33		32	
	Middle adult	Left side higher	6	17.6	6	31.6	8	25.0	5	31.3	2	6.3	2	12.5	1	3.0	1	5.6
		Equal	23	67.6	13	68.4	17	53.1	10	62.5	27	84.4	13	81.3	29	87.9	17	94.4
		Right side higher	5	14.7	0	0.0	7	21.9	1	6.3	3	9.4	1	6.3	3	9.1	0	0.0
		Total	34		19		32		16		32		16		33		18	
	Old adult	Left side higher	3	9.4	0	0.0	3	10.0	5	35.7	4	13.3	2	14.3	1	3.3	1	6.7
		Equal	25	78.1	14	93.3	22	73.3	8	57.1	18	60.0	10	71.4	28	93.3	12	80.0
		Right side higher	4	12.5	1	6.7	5	16.7	1	7.1	8	26.7	2	14.3	1	3.3	2	13.3
		Total	32		15		30		14		30		14		30		15	
Supraspinatus	Young adult	Left side higher	5	13.9	4	11.4	1	3.3	0	0.0	0	0.0	0	0.0	1	3.2	1	3.3
		Equal	29	80.6	29	82.9	29	96.7	25	100.0	30	100	25	100	30	96.8	28	93.3
		Right side higher	2	5.6	2	5.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	3.3
		Total	36		35		30		25		30		25		31		30	
	Middle adult	Left side higher	2	5.9	2	10.5	3	10.0	0	0.0	1	3.3	0	0.0	1	3.2	1	7.1
		Equal	29	85.3	16	84.2	27	90.0	12	100.0	27	90.0	12	100	28	90.3	12	85.7
		Right side higher	3	8.8	1	5.3	0	0.0	0	0.0	2	6.7	0	0.0	2	6.5	1	7.1
		Total	34		19		30		12		30		12		31		14	
	Old adult	Left side higher	7	21.9	2	13.3	6	22.2	0	0.0	0	0.0	1	7.7	2	7.1	0	0.0
		Equal	19	59.4	11	73.3	19	70.4	12	92.3	23	85.2	8	61.5	24	85.7	12	85.7
		Right side higher	6	18.8	2	13.3	2	7.4	1	7.7	4	14.8	4	30.8	2	7.1	2	14.3
		Total	32		15		27		13		27		13		28		14	
Infraspinatus	Young adult	Left side higher	2	5.6	4	11.4	0	0.0	0	0.0	0	0.0	0	0.0	2	6.3	2	9.1
		Equal	27	75.0	27	77.1	32	100.0	21	100.0	32	100.0	21	100	29	90.6	19	86.4
		Right side higher	7	19.4	4	11.4	0	0.0	0	0.0	0	0.0	0	0.0	1	3.1	1	4.5
		Total	36		35		32		21		32		21		32		22	
	Middle adult	Left side higher	4	11.8	2	10.5	1	3.4	0	0.0	0	0.0	0	0.0	2	6.9	0	0.0
		Equal	21	61.8	13	68.4	28	96.6	10	100.0	29	100.0	10	100	23	79.3	11	100.0
		Right side higher	9	26.5	4	21.1	0	0.0	0	0.0	0	0.0	0	0.0	4	13.8	0	0.0
		Total	34		19		29		10		29		10		29		11	
	Old adult	Left side higher	9	28.1	6	40.0	2	7.4	1	8.3	0	0.0	0	0.0	1	3.6	1	8.3
		Equal	20	62.5	7	46.7	22	81.5	11	91.7	27	100.0	12	100	27	96.4	11	91.7

		Right side higher	3	9.4	2	13.3	3	11.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
		Total	32		15		27		12		27		12		28		12	
Common extensor origin	Young adult	Left side higher	6	16.7	2	5.7	0	0.0	1	4.0	0	0.0	0	0.0	1	3.4	0	0.0
		Equal	21	58.3	28	80.0	28	93.3	24	96.0	29	96.7	25	100	28	96.6	26	96.3
		Right side higher	9	25.0	5	14.3	2	6.7	0	0.0	1	3.3	0	0.0	0	0.0	1	3.7
		Total	36		35		30		25		30		25		29		27	
	Middle adult	Left side higher	7	20.6	5	26.3	5	17.2	3	27.3	2	6.9	0	0.0	3	10.3	1	7.7
		Equal	20	58.8	13	68.4	22	75.9	8	72.7	27	93.1	11	100	24	82.8	11	84.6
		Right side higher	7	20.6	1	5.3	2	6.9	0	0.0	0	0.0	0	0.0	2	6.9	1	7.7
		Total	34		19		29		11		29		11		29		13	
	Old adult	Left side higher	4	12.5	2	13.3	1	4.2	2	20.0	1	4.2	0	0.0	2	7.7	0	0.0
		Equal	24	75.0	12	80.0	23	95.8	7	70.0	22	91.7	10	100	21	80.8	11	100.0
		Right side higher	4	12.5	1	6.7	0	0.0	1	10.0	1	4.2	0	0	3	11.5	0	0.0
		Total	32		15		24		10		24		10		26		11	
Common flexor origin	Young adult	Left side higher	8	22.2	6	17.1	1	3.4	1	3.7	0	0.0	0	0.0	0	0.0	0	0.0
		Equal	25	69.4	28	80.0	28	96.6	25	92.6	28	96.6	26	96.3	30	100.0	25	100.0
		Right side higher	3	8.3	1	2.9	0	0.0	1	3.7	1	3.4	1	3.7	0	0.0	0	0.0
		Total	36		35		29		27		29		27		30		25	
	Middle adult	Left side higher	4	11.8	4	21.1	3	12.0	2	18.2	0	0.0	0	0.0	1	3.8	0	0.0
		Equal	24	70.6	13	68.4	19	76.0	9	81.8	24	96.0	11	100	25	96.2	10	90.9
		Right side higher	6	17.6	2	10.5	3	12.0	0	0.0	1	4.0	0	0.0	0	0.0	1	9.1
		Total	34		19		25		11		25		11		26		11	
	Old adult	Left side higher	3	9.4	1	6.7	3	15.8	0	0.0	0	0.0	0	0.0	2	9.1	0	0.0
		Equal	24	75.0	13	86.7	12	63.2	10	90.9	19	100.0	11	100	20	90.9	12	100.0
		Right side higher	5	15.6	1	6.7	4	21.1	1	9.1	0	0.0	0	0.0	0	0.0	0	0.0
		Total	32		15		19		11		19		11		22		12	
Biceps brachii	Young adult	Left side higher	4	11.1	0	0.0	7	20.6	0	0.0	1	2.9	3	10.0	2	6.1	1	3.0
		Equal	32	88.9	29	82.9	24	70.6	25	83.3	29	85.3	26	86.7	28	84.8	26	78.8
		Right side higher	0	0.0	6	17.1	3	8.8	5	16.7	4	11.8	1	3.3	3	9.1	6	18.2
		Total	36		35		34		30		34		30		33		33	
	Middle adult	Left side higher	1	2.9	1	5.3	4	12.5	2	11.8	2	6.3	2	11.8	6	18.8	2	11.1
		Equal	32	94.1	17	89.5	26	81.3	15	88.2	28	87.5	14	82.4	24	75.0	10	55.6
		Right side higher	1	2.9	1	5.3	2	6.3	0	0.0	2	6.3	1	5.9	2	6.3	6	33.3
		Total	34		19		32		17		32		17		32		18	
	Old adult	Left side higher	1	3.1	2	13.3	0	0.0	0	0.0	4	13.3	0	0.0	5	17.2	0	0.0
		Equal	30	93.8	13	86.7	27	90.0	11	84.6	25	83.3	13	100	19	65.5	11	84.6
		Right side higher	1	3.1	0	0.0	3	10.0	2	15.4	1	3.3	0	0.0	5	17.2	2	15.4
		Total	32		15		30		13		30		13		29		13	
Triceps brachii	Young adult	Left side higher	7	19.4	3	8.6	2	7.4	2	8.7	0	0.0	0	0.0	1	3.3	2	8.0
		Equal	23	63.9	24	68.6	25	92.6	17	73.9	26	96.3	23	100	28	93.3	20	80.0

	Right side higher	6	16.7	8	22.9	0	0.0	4	17.4	1	3.7	0	0.0	1	3.3	3	12.0
	Total	36		35		27		23		27		23		30		25	
Middle adult	Left side higher	8	23.5	3	15.8	7	28.0	1	9.1	1	4.0	1	9.1	3	11.1	0	0.0
	Equal	21	61.8	14	73.7	16	64.0	10	90.9	21	84.0	10	90.9	23	85.2	12	85.7
	Right side higher	5	14.7	2	10.5	2	8.0	0	0.0	3	12.0	0	0.0	1	3.7	2	14.3
	Total	34		19		25		11		25		11		27		14	
Old adult	Left side higher	4	12.5	5	33.3	6	25.0	6	60.0	4	16.7	0	0.0	1	3.7	2	18.2
	Equal	26	81.3	9	60.0	17	70.8	4	40.0	19	79.2	10	100	23	85.2	9	81.8
	Right side higher	2	6.3	1	6.7	1	4.2	0	0.0	1	4.2	0	0.0	3	11.1	0	0.0
	Total	32		15		24		10		24		10		27		11	

f= frequency, BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change.

Continuation appendix 5. Asymmetry in the upper limbs by age range comparing the two skeletal collections.

			BF(Z2)				**ER(Z2)**				**FPO**				**MPO**				**CA**			
			NILMFS		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**	
Enthesis	**Age range**	**Asymmetry**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**
Subscapularis	Young adult	Left side higher	3	9.1	3	9.4	4	12.1	2	6.1	2	6.1	0	0.0	2	6.1	0	0.0	2	6.1	0	0.0
		Equal	26	78.8	28	87.5	28	84.8	30	90.9	29	87.9	33	100.0	31	93.9	33	100.0	31	93.9	33	100.0
		Right side higher	4	12.1	1	3.1	1	3.0	1	3.0	2	6.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
		Total	33		32		33		33		33		33		33		33		33		33	
	Middle adult	Left side higher	13	39.4	5	27.8	9	27.3	5	27.8	2	6.1	2	11.1	4	12.1	1	5.6	1	3.0	0	0.0
		Equal	17	51.5	12	66.7	20	60.6	12	66.7	28	84.8	15	83.3	26	78.8	17	94.4	28	84.8	18	100.0
		Right side higher	3	9.1	1	5.6	4	12.1	1	5.6	3	9.1	1	5.6	3	9.1	0	0.0	4	12.1	0	0.0
		Total	33		18		33		18		33		18		33		18		33		18	
	Old adult	Left side higher	1	3.3	3	20.0	6	20.0	2	13.3	3	10.0	0	0.0	4	13.3	3	20.0	3	10.0	0	0.0
		Equal	23	76.7	8	53.3	22	73.3	13	86.7	24	80.0	15	100.0	21	70.0	11	73.3	24	80.0	15	100.0
		Right side higher	6	20.0	4	26.7	2	6.7	0	0.0	3	10.0	0	0.0	5	16.7	1	6.7	3	10.0	0	0.0
		Total	30		15		30		15		30		15		30		15		30		15	
Supraspinatus	Young adult	Left side higher	1	3.2	1	3.3	0	0.0	1	3.3	2	6.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
		Equal	30	96.8	29	96.7	30	96.8	29	96.7	28	90.3	29	96.7	30	96.8	30	100.0	31	100.0	30	100.0
		Right side higher	0	0.0	0	0.0	1	3.2	0	0.0	1	3.2	1	3.3	1	3.2		0.0	0	0.0	0	0.0
		Total	31		30		31		30		31		30		31		30		31		30	
	Middle adult	Left side higher	1	3.2	2	14.3	2	6.5	0	0.0	2	6.5	0	0.0	2	6.5	0	0.0	0	0.0	0	0.0
		Equal	27	87.1	12	85.7	26	83.9	14	100.0	26	83.9	13	92.9	28	90.3	14	100.0	31	100.0	14	100.0
		Right side higher	3	9.7	0	0.0	3	9.7	0	0.0	3	9.7	1	7.1	1	3.2	0	0.0	0	0.0	0	0.0
		Total	31		14		31		14		31		14		31		14		31		14	
	Old adult	Left side higher	5	17.9	1	7.1	6	21.4	2	14.3	3	10.7	1	7.1	2	7.1	2	14.3	3	10.7	1	7.1
		Equal	20	71.4	13	92.9	19	67.9	9	64.3	22	78.6	12	85.7	25	89.3	12	85.7	24	85.7	13	92.9

		Right side higher	3	10.7	0	0.0	3	10.7	3	21.4	3	10.7	1	7.1	1	3.6	0	0.0	1	3.6	0	0.0
		Total	28		14		28		14		28		14		28		14		28		14	
Infraspinatus	Young adult	Left side higher	1	3.1	1	4.5	1	3.1	1	4.5	1	3.1	1	4.5	0	0.0	1	4.5	0	0.0	0	0.0
		Equal	30	93.8	20	90.9	30	93.8	21	95.5	26	81.3	20	90.9	32	100.0	21	95.5	32	100.0	22	100.0
		Right side higher	1	3.1	1	4.5	1	3.1	0	0.0	5	15.6	1	4.5	0	0.0	0	0.0	0	0.0	0	0.0
		Total	32		22		32		22		32		22		32		22		32		22	
	Middle adult	Left side higher	1	3.4	0	0.0	3	10.3	0	0.0	0	0.0	0	0.0	1	3.4	0	0.0	1	3.4	0	0.0
		Equal	21	72.4	10	90.9	24	82.8	9	81.8	24	82.8	10	90.9	28	96.6	11	100.0	27	93.1	11	100.0
		Right side higher	7	24.1	1	9.1	2	6.9	2	18.2	5	17.2	1	9.1	0	0.0	0	0.0	1	3.4	0	0.0
		Total	29		11		29		11		29		11		29		11		29		11	
	Old adult	Left side higher	5	17.9	0	0.0	6	21.4	1	8.3	3	10.7	2	16.7	1	3.6	2	16.7	0	0.0	0	0.0
		Equal	18	64.3	11	91.7	19	67.9	10	83.3	25	89.3	10	83.3	26	92.9	9	75.0	27	96.4	12	100.0
		Right side higher	5	17.9	1	8.3	3	10.7	1	8.3	0	0.0	0	0.0	1	3.6	1	8.3	1	3.6	0	0.0
		Total	28		12		28		12		28		12		28		12		28		12	
Common extensor origin	Young adult	Left side higher	1	3.4	0	0.0	2	6.9	0	0.0	2	6.9	0	0.0	1	3.4	0	0.0	0	0.0		0.0
		Equal	27	93.1	26	96.3	24	82.8	26	96.3	25	86.2	26	96.3	27	93.1	26	96.3	29	100.0	27	100.0
		Right side higher	1	3.4	1	3.7	3	10.3	1	3.7	2	6.9	1	3.7	1	3.4	1	3.7	0	0.0		0.0
		Total	29		27		29		27		29		27		29		27		29		27	
	Middle adult	Left side higher	6	20.7	3	23.1	1	3.4	1	7.7	4	13.8	0	0.0	3	10.3	1	7.7	0	0.0	0	0.0
		Equal	16	55.2	10	76.9	28	96.6	12	92.3	25	86.2	13	100.0	26	89.7	12	92.3	29	100.0	13	100.0
		Right side higher	7	24.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
		Total	29		13		29		13		29		13		29		13		29		13	
	Old adult	Left side higher	1	3.8	3	27.3	7	26.9	1	9.1	4	15.4	0	0.0	3	11.5	0	0.0	0	0.0	0	0.0
		Equal	23	88.5	5	45.5	15	57.7	10	90.9	22	84.6	11	100.0	21	80.8	11	100.0	26	100.0	11	100.0
		Right side higher	2	7.7	3	27.3	4	15.4	0	0.0	0	0.0	0	0.0	2	7.7	0	0.0	0	0.0	0	0.0
		Total	26		11		26		11		26		11		26		11		26		11	
Common flexor origin	Young adult	Left side higher	4	13.3	3	12.0	2	6.7	0	0.0	1	3.3	1	4.0	0	0.0	1	4.0	0	0.0	0	0.0
		Equal	25	83.3	22	88.0	27	90.0	24	96.0	29	96.7	24	96.0	30	100.0	24	96.0	30	100.0	25	100.0
		Right side higher	1	3.3	0	0.0	1	3.3	1	4.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
		Total	30		25		30		25		30		25		30		25		30		25	
	Middle adult	Left side higher	5	19.2	3	27.3	6	23.1	1	9.1	1	3.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
		Equal	16	61.5	8	72.7	18	69.2	8	72.7	22	84.6	11	100.0	25	96.2	11	100.0	26	100.0	11	100.0
		Right side higher	5	19.2	0	0.0	2	7.7	2	18.2	3	11.5	0	0.0	1	3.8	0	0.0	0	0.0	0	0.0
		Total	26		11		26		11		26		11		26		11		26		11	
	Old adult	Left side higher	2	9.1	2	16.7	6	27.3	2	16.7	5	22.7	1	8.3	0	0.0	0	0.0	0	0.0	0	0.0
		Equal	14	63.6	9	75.0	12	54.5	8	66.7	16	72.7	11	91.7	21	95.5	12	100.0	22	100.0	12	100.0
		Right side higher	6	27.3	1	8.3	4	18.2	2	16.7	1	4.5	0	0.0	1	4.5	0	0.0	0	0.0	0	0.0
		Total	22		12		22		12		22		12		22		12		22		12	
Biceps brachii	Young adult	Left side higher	2	6.1	6	18.2	3	9.1	5	15.2	0	0.0	0	0.0	1	3.0	1	3.0	0	0.0	0	0.0
		Equal	27	81.8	23	69.7	29	87.9	26	78.8	33	100.0	32	97.0	31	93.9	32	97.0	33	100.0	33	100.0

		Right side higher	4	12.1	4	12.1	1	3.0	2	6.1	0	0.0	1	3.0	1	3.0	0	0.0	0	0.0	0	0.0
		Total	33		33		33		33		33		33		33		33		33		33	
	Middle adult	Left side higher	2	6.3	5	27.8	2	6.3	1	5.6	2	6.3	1	5.6	0	0.0	0	0.0	1	3.1	0	0.0
		Equal	26	81.3	11	61.1	27	84.4	12	66.7	29	90.6	16	88.9	32	100.0	18	100.0	31	96.9	18	100.0
		Right side higher	4	12.5	2	11.1	3	9.4	5	27.8	1	3.1	1	5.6	0	0.0	0	0.0	0	0.0	0	0.0
		Total	32		18		32		18		32		18		32		18		32		18	
	Old adult	Left side higher	3	10.3	2	15.4	6	20.7	5	38.5	2	6.9	0	0.0	2	6.9	1	7.7	1	3.4	0	0.0
		Equal	22	75.9	9	69.2	16	55.2	7	53.8	26	89.7	13	100.0	23	79.3	10	76.9	26	89.7	12	92.3
		Right side higher	4	13.8	2	15.4	7	24.1	1	7.7	1	3.4	0	0.0	4	13.8	2	15.4	2	6.9	1	7.7
		Total	29		13		29		13		29		13		29		13		29		13	
Triceps brachii	Young adult	Left side higher	2	6.7	2	8.0	8	26.7	3	12.0	0	0.0	1	4.0	0	0.0	1	4.0	0	0.0	0	0.0
		Equal	25	83.3	20	80.0	21	70.0	15	60.0	26	86.7	23	92.0	30	100.0	22	88.0	30	100.0	25	100.0
		Right side higher	3	10.0	3	12.0	1	3.3	7	28.0	4	13.3	1	4.0	0	0.0	2	8.0	0	0.0	0	0.0
		Total	30		25		30		25		30		25		30		25		30		25	
	Middle adult	Left side higher	4	14.8	0	0.0	1	3.7	5	35.7	2	7.4	1	7.1	1	3.7	0	0.0	0	0.0	0	0.0
		Equal	18	66.7	12	85.7	23	85.2	9	64.3	22	81.5	13	92.9	25	92.6	12	85.7	27	100.0	14	100.0
		Right side higher	5	18.5	2	14.3	3	11.1	0	0.0	3	11.1	0	0.0	1	3.7	2	14.3	0	0.0	0	0.0
		Total	27		14		27		14		27		14		27		14		27		14	
	Old adult	Left side higher	7	25.9	0	0.0	2	7.4	2	18.2	1	3.7	0	0.0	0	0.0	1	9.1	0	0.0	0	0.0
		Equal	16	59.3	9	81.8	24	88.9	8	72.7	25	92.6	11	100.0	27	100.0	10	90.9	27	100.0	11	100.0
		Right side higher	4	14.8	2	18.2	1	3.7	1	9.1	1	3.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
		Total	27		11		27		11		27		11		27		11		27		11	

f= frequency, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.

Appendix 7. Comparison of frequencies of bilateral asymmetry in joint complexes of the upper limbs.

			Overall				**BF(Z1)**				**ER(Z1)**				**TC**				**BF(Z2)**			
			NILMFS		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**	
Joint	**Age range**	**Asymmetry**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**
Shoulder	Young adult	Left side higher	7	19.4	9	25.7	8	22.2	1	2.9	0	0.0	0	0.0	3	8.3	5	14.3	3	8.3	6	17.1
		Equal	25	69.4	23	65.7	26	72.2	33	94.3	35	97.2	34	97.1	31	86.1	27	77.1	31	86.1	27	77.1
		Right side higher	4	11.1	3	8.6	2	5.6	1	2.9	1	2.8	1	2.9	2	5.6	3	8.6	2	5.6	2	5.7
		Total	36		35		36		35		36		35		36		35		36		35	
	Middle adult	Left side higher	5	14.7	6	31.6	9	26.5	6	31.6	3	8.8	2	10.5	2	5.9	2	10.5	9	26.5	8	42.1
		Equal	24	70.6	12	63.2	18	52.9	12	63.2	27	79.4	16	84.2	26	76.5	16	84.2	20	58.8	9	47.4
		Right side higher	5	14.7	1	5.3	7	20.6	1	5.3	4	11.8	1	5.3	6	17.6	1	5.3	5	14.7	2	10.5
		Total	34		19		34		19		34		19		34		19		34		19	
	Old adult	Left side higher	2	6.3	0	0.0	1	3.1	4	26.7	3	9.4	2	13.3	2	6.3	2	13.3	3	9.4	2	13.3
		Equal	28	87.5	14	93.3	28	87.5	10	66.7	21	65.6	8	53.3	28	87.5	11	73.3	23	71.9	10	66.7
		Right side higher	2	6.3	1	6.7	3	9.4	1	6.7	8	25.0	5	33.3	2	6.3	2	13.3	6	18.8	3	20.0
		Total	32		15		32		15		32		15		32		15		32		15	
Elbow	Young adult	Left side higher	3	8.3	0	0.0	6	16.7	1	2.9	1	2.8	3	8.6	3	8.3	3	8.6	4	11.1	6	17.1
		Equal	32	88.9	30	85.7	27	75.0	29	82.9	30	83.3	31	88.6	30	83.3	25	71.4	25	69.4	25	71.4
		Right side higher	1	2.8	5	14.3	3	8.3	5	14.3	5	13.9	1	2.9	3	8.3	7	20.0	7	19.4	4	11.4
		Total	36		35		36		35		36		35		36		35		36		35	
	Middle adult	Left side higher	0	0.0	1	5.3	5	14.7	3	15.8	4	11.8	3	15.8	7	20.6	2	10.5	5	14.7	4	21.1
		Equal	34	100.0	18	94.7	27	79.4	15	78.9	25	73.5	15	78.9	25	73.5	10	52.6	22	64.7	14	73.7
		Right side higher	0	0.0	0	0.0	2	5.9	1	5.3	5	14.7	1	5.3	2	5.9	7	36.8	7	20.6	1	5.3
		Total	34		19		34		19		34		19		34		19		34		19	
	Old adult	Left side higher	1	3.1	1	6.7	2	6.3	2	13.3	7	21.9	0	0.0	3	9.4	3	20.0	7	21.9	1	6.7
		Equal	30	93.8	14	93.3	28	87.5	11	73.3	23	71.9	15	100.0	25	78.1	11	73.3	19	59.4	12	80.0
		Right side higher	1	3.1	0	0.0	2	6.3	2	13.3	2	6.3	0	0.0	4	12.5	1	6.7	6	18.8	2	13.3
		Total	32		15		32		15		32		15		32		15		32		15	
Wrist/hand		Left side higher	9	25.0	7	20.0	1	2.8	3	8.6	0	0.0	0	0.0	1	2.8	0	0.0	5	13.9	5	14.3

	Young adult	Equal	15	41.7	23	65.7	32	88.9	31	88.6	34	94.4	34	97.1	35	97.2	34	97.1	28	77.8	29	82.9
		Right side higher	12	33.3	5	14.3	3	8.3	1	2.9	2	5.6	1	2.9	0	0.0	1	2.9	3	8.3	1	2.9
		Total	36		35		36		35		36		35		36		35		36		35	
	Middle adult	Left side higher	7	20.6	4	21.1	5	14.7	5	26.3	2	5.9	0	0.0	4	11.8	0	0.0	7	20.6	6	31.6
		Equal	20	58.8	12	63.2	27	79.4	12	63.2	31	91.2	19	100.0	27	79.4	18	94.7	20	58.8	12	63.2
		Right side higher	7	20.6	3	15.8	2	5.9	2	10.5	1	2.9	0	0.0	3	8.8	1	5.3	7	20.6	1	5.3
		Total	34		19		34		19		34		19		34		19		34		19	
	Old adult	Left side higher	2	6.3	2	13.3	2	6.3	3	20.0	1	3.1	0	0.0	3	9.4	1	6.7	2	6.3	3	20.0
		Equal	26	81.3	13	86.7	27	84.4	11	73.3	30	93.8	15	100.0	25	78.1	14	93.3	27	84.4	11	73.3
		Right side higher	4	12.5	0	0.0	3	9.4	1	6.7	1	3.1	0	0.0	4	12.5	0	0.0	3	9.4	1	6.7
		Total	32		15		32		15		32		15		32		15		32		15	

f= frequency, BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2.

Continuation appendix 6. Comparison of frequencies of bilateral asymmetry in joint complexes of the upper limbs.

			ER(Z2)				**FPO**				**MPO**				**CA**			
			NILMFS		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**		**NILMFS**		**UdeA**	
Joint	**Age range**	**Asymmetry**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**	***f***	**%**
Shoulder	Young adult	Left side higher	5	13.9	4	11.4	0	0.0	1	2.9	2	5.6	1	2.9	2	5.6	0	0.0
		Equal	29	80.6	30	85.7	31	86.1	32	91.4	33	91.7	34	97.1	34	94.4	35	100.0
		Right side higher	2	5.6	1	2.9	5	13.9	2	5.7	1	2.8	0	0.0	0	0.0	0	0.0
		Total	36		35		36		35		36		35		36		35	
	Middle adult	Left side higher	7	20.6	6	31.6	1	2.9	3	15.8	6	17.6	1	5.3	2	5.9	0	0.0
		Equal	21	61.8	11	57.9	28	82.4	13	68.4	24	70.6	18	94.7	28	82.4	19	100.0
		Right side higher	6	17.6	2	10.5	5	14.7	3	15.8	4	11.8	0	0.0	4	11.8	0	0.0
		Total	34		19		34		19		34		19		34		19	
	Old adult	Left side higher	4	12.5	2	13.3	5	15.6	3	20.0	5	15.6	6	40.0	5	15.6	1	6.7
		Equal	27	84.4	12	80.0	25	78.1	11	73.3	22	68.8	8	53.3	24	75.0	14	93.3
		Right side higher	1	3.1	1	6.7	2	6.3	1	6.7	5	15.6	1	6.7	3	9.4	0	0.0
		Total	32		15		32		15		32		15		32		15	

Elbow	Young adult	Left side higher	10	27.8	6	17.1	1	2.8	1	2.9	1	2.8	2	5.7	0	0.0	0	0.0
		Equal	23	63.9	23	65.7	31	86.1	32	91.4	33	91.7	31	88.6	36	100.0	35	100.0
		Right side higher	3	8.3	6	17.1	4	11.1	2	5.7	2	5.6	2	5.7	0	0.0	0	0.0
		Total	36		35		36		35		36		35		36		35	
	Middle adult	Left side higher	2	5.9	3	15.8	2	5.9	2	10.5	1	2.9	0	0.0	1	2.9	0	0.0
		Equal	28	82.4	12	63.2	30	88.2	16	84.2	32	94.1	16	84.2	33	97.1	19	100.0
		Right side higher	4	11.8	4	21.1	2	5.9	1	5.3	1	2.9	3	15.8	0	0.0	0	0.0
		Total	34		19		34		19		34		19		34		19	
	Old adult	Left side higher	7	21.9	4	26.7	2	6.3	0	0.0	2	6.3	1	6.7	1	3.1	0	0.0
		Equal	18	56.3	11	73.3	29	90.6	15	100.0	26	81.3	13	86.7	29	90.6	14	93.3
		Right side higher	7	21.9	0	0.0	1	3.1	0	0.0	4	12.5	1	6.7	2	6.3	1	6.7
		Total	32		15		32		15		32		15		32		15	
Wrist/hand	Young adult	Left side higher	3	8.3	0	0.0	3	8.3	2	5.7	1	2.8	1	2.9	0	0.0	0	0.0
		Equal	30	83.3	33	94.3	31	86.1	32	91.4	34	94.4	33	94.3	36	100.0	35	100.0
		Right side higher	3	8.3	2	5.7	2	5.6	1	2.9	1	2.8	1	2.9	0	0.0	0	0.0
		Total	36		35		36		35		36		35		36		35	
	Middle adult	Left side higher	6	17.6	3	15.8	3	8.8	0	0.0	3	8.8	1	5.3	0	0.0	0	0.0
		Equal	24	70.6	13	68.4	29	85.3	19	100.0	30	88.2	18	94.7	34	100.0	19	100.0
		Right side higher	4	11.8	3	15.8	2	5.9	0	0.0	1	2.9	0	0.0	0	0.0	0	0.0
		Total	34		19		34		19		34		19		34		19	
	Old adult	Left side higher	4	12.5	3	20.0	9	28.1	1	6.7	4	12.5	0	0.0	0	0.0	0	0.0
		Equal	22	68.8	12	80.0	22	68.8	14	93.3	25	78.1	15	100.0	32	100.0	15	100.0
		Right side higher	6	18.8	0	0.0	1	3.1	0	0.0	3	9.4	0	0.0	0	0.0	0	0.0
		Total	32		15		32		15		32		15		32		15	

f= frequency, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.

Appendix 8.Frequencies of score 1 and 2 of EC in the entheses in the lower limbs of the male individuals from the UdeA skeletal collection.

			BF (Z1)		**ER (Z1)**		**TC**		**BF (Z2)**		**ER (Z2)**		**FPO**		**MPO**		**CA**	
Enthesis	**Side**	**Score**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**
Iliopsoas	Right	0	54	78.3	61	88.4	46	66.7	53	76.8	44	63.8	59	85.5	60	87	62	0
		1	8	11.6	1	1.4	16	23.2	8	11.6	17	24.6	3	4.3	2	2.9	0	0
		2	**0**	**0**	0	0	-	-	1	1.4	1	1.4	0	0	0	0	0	0
		NR	7	10.1	7	10.1	7	10.1	7	10.1	7	10.1	7	10.1	7	10.1	7	10.1
	Left	0	50	72.5	59	85.5	44	63.8	49	71	36	52.2	58	84.1	59	85.5	61	88.4
		1	9	13	0	0	17	24.6	12	17.4	24	34.8	3	4.3	1	1.4	0	0
		2	0	0	0	0	-	-	0	0	1	1.4	0	0	1	1.4	0	0
		NR	10	14.5	10	14.5	8	11.6	8	11.6	8	11.6	8	11.6	8	11.6	8	11.6
Gastrocnemius	Right	0	60	87	65	94.2	46	66.7	63	91.3	60	87	64	92.8	66	95.7	67	97.1
		1	6	8.7	1	1.4	21	30.4	4	5.8	7	10.1	3	4.3	1	1.4	0	0
		2	0	0	0	0	-	-	0	0	0	0	0	0	0	0	0	0
		NR	3	4.3	3	4.3	2	2.9	2	2.9	2	2.9	2	2.9	2	2.9	2	2.9
	Left	0	61	88.4	66	95.7	40	58	60	87	52	75.4	67	97.1	66	95.7	67	97.1
		1	5	7.2	0	0	27	39.1	7	10.1	14	20.3	0	0	1	1.4	0	0
		2	0	0	0	0	-	-	0	0	1	1.4	0	0	0	0	0	0
		NR	3	4.3	3	4.3	2	2.9	2	2.9	2	2.9	2	2.9	2	2.9	2	2.9
Quadriceps femoris	Right	0	26	37.7	54	78.3	38	55.1	44	63.8	48	69.6	59	85.5	59	85.5	59	85.5
		1	31	44.9	4	5.8	21	30.4	15	21.7	11	15.9	0	0	0	0	0	0
		2	1	1.4	0	0	-	-	0	0	0	0	0	0	0	0	0	0
		NR	11	15.9	11	15.9	10	14.5	10	14.5	10	14.5	10	14.5	10	14.5	10	14.5
	Left	0	28	40.6	50	72.5	42	60.9	41	59.4	47	68.1	59	85.5	59	85.5	60	87
		1	31	44.9	10	14.5	18	26.1	19	27.5	12	17.4	1	1.4	1	1.4	0	0
		2	1	1.4	0	0	-	-	0	0	1	1.4	0	0	0	0	0	0
		NR	9	13	9	13	9	13	9	13	9	13	9	13	9	13	9	13
Vastus Lateralis	Right	0	27	39.1	52	75.4	19	27.5	52	75.4	49	71	56	81.2	56	81.2	56	81.2
		1	27	39.1	1	1.4	37	53.6	4	5.8	4	5.8	0	0	0	0	0	0
		2	0	0	1	1.4	-	-	0	0	3	4.3	0	0	0	0	0	0
		NR	15	21.7	15	21.7	13	18.8	13	18.8	13	18.8	13	18.8	13	18.8	13	18.8
	Left	0	28	40.6	52	75.4	19	27.5	50	72.5	50	72.5	53	76.8	54	78.3	54	78.3
		1	27	39.1	2	2.9	35	50.7	4	5.8	1	1.4	1	1.4	0	0	0	0
		2	0	0	1	1.4	-	-	0	0	3	4.3	0	0	0	0	0	0
		NR	14	20.3	14	20.3	15	21.7	15	21.7	15	21.7	15	21.7	15	21.7	15	21.7
Patellar ligament	Right	0	29	42	56	81.2	45	65.2	52	75.4	56	81.2	55	79.7	58	84.1	58	84.1
		1	27	39.1	2	2.9	13	18.8	6	8.7	1	1.4	3	4.3	0	0	0	0
		2	2	2.9	0	0	-	-	0	0	1	1.4	0	0	0	0	0	0
		NR	11	15.9	11	15.9	11	15.9	11	15.9	11	15.9	11	15.9	11	15.9	11	15.9
	Left	0	28	40.6	58	84.1	46	66.7	48	69.6	57	82.6	57	82.6	60	87	61	88.4
		1	28	40.6	0	0	15	21.7	12	17.4	3	4.3	4	5.8	1	1.4	0	0
		2	2	2.9	0	0	-	-	1	1.4	1	1.4	0	0	0	0	0	0
		NR	11	15.9	11	15.9	8	11.6	8	11.6	8	11.6	8	11.6	8	11.6	8	11.6
Triceps surae	Right	0	10	14.5	59	85.5	48	69.6	33	47.8	59	85.5	57	82.6	60	87	60	87
		1	49	71	1	1.4	12	17.4	27	39.1	1	1.4	3	4.3	0	0	0	0
		2	1	1.4	0	0	-	-	0	0	0	0	0	0	0	0	0	0
		NR	9	13	9	13	9	13	9	13	9	13	9	13	9	13	9	13
	Left	0	13	18.8	61	88.4	45	65.2	40	58	59	85.5	62	89.9	62	89.9	64	92.8

		1	47	68.1	0	0	19	27.5	24	34.8	5	7.2	2	2.9	2	2.9	0	0
		2	1	1.4	0	0	-	-	0	0	0	0	0	0	0	0	0	0
		NR	8	11.6	8	11.6	5	7.2	5	7.2	5	7.2	5	7.2	5	7.2	5	7.2
Plantar Fascia	Right	0	27	39.1	59	85.5	-	-	-	-	-	-	-	-	-	-	-	-
		1	29	42	0	0	-	-	-	-	-	-	-	-	-	-	-	-
		2	3	4.3	0	0	-	-	-	-	-	-	-	-	-	-	-	-
		NR	10	14.5	10	14.5	-	-	-	-	-	-	-	-	-	-	-	-
	Left	0	34	49.3	58	84.1	-	-	-	-	-	-	-	-	-	-	-	-
		1	24	34.8	0	0	-	-	-	-	-	-	-	-	-	-	-	-
		2	1	1.4	0	0	-	-	-	-	-	-	-	-	-	-	-	-
		NR	10	14.5	11	15.9	-	-	-	-	-	-	-	-	-	-	-	-

f= frequency, NR= No recordable, BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.

Appendix 9. Frequencies of EC by age range, of the lower limbs entheses of the UdeA skeletal collection.

		Age	BF (Z1)			ER (Z1)			TC			BF (Z2)			ER (Z2)			FPO			MPO			CA		
Side	**Enthesis**	**range**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**
Left	Gastrocnemius	20-35	34	2	6%	34	0	0%	34	14	41%	34	2	6%	34	6	18%	34	0	0%	34	1	3%	34	0	0%
		36-50	20	0	0%	20	0	0%	20	8	40%	20	4	20%	20	3	15%	20	0	0%	20	0	0%	20	0	0%
		50-68	12	3	25%	12	0	0%	13	5	38%	13	1	8%	13	6	46%	13	0	0%	13	0	0%	13	0	0%
	Iliopsoas	20-35	31	2	6%	31	0	0%	33	8	24%	33	4	12%	33	10	30%	33	3	9%	33	2	6%	33	0	0%
		36-50	16	4	25%	16	0	0%	16	7	44%	16	4	25%	16	9	56%	16	0	0%	16	0	0%	16	0	0%
		50-68	12	3	25%	12	0	0%	12	2	17%	12	4	33%	12	6	50%	12	0	0%	12	0	0%	12	0	0%
	Patellar ligament	20-35	30	10	33%	30	0	0%	31	7	23%	31	3	10%	31	1	3%	31	1	3%	31	1	3%	31	0	0%
		36-50	15	11	73%	15	0	0%	17	3	18%	17	4	24%	17	1	6%	17	3	18%	17	0	0%	17	0	0%
		50-68	13	9	69%	13	0	0%	13	5	38%	13	6	46%	13	2	15%	13	0	0%	13	0	0%	13	0	0%
	Plantar fascia	20-35	32	10	31%	32	0	0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		36-50	16	10	63%	15	0	0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		50-68	11	5	45%	11	0	0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Quadriceps femoris	20-35	30	15	50%	30	4	13%	30	9	30%	30	5	17%	30	7	23%	30	1	3%	30	0	0%	30	0	0%
		36-50	18	11	61%	18	4	22%	18	5	28%	18	7	39%	18	4	22%	18	0	0%	18	0	0%	18	0	0%
		51-68	12	6	50%	12	2	17%	12	4	33%	12	7	58%	12	2	17%	12	0	0%	12	1	8%	12	0	0%
	Triceps surae	20-35	31	19	61%	31	0	0%	33	8	24%	33	4	12%	33	3	9%	33	1	3%	33	2	6%	33	0	0%
		36-50	16	15	94%	16	0	0%	17	6	35%	17	11	65%	17	0	0%	17	1	6%	17	0	0%	17	0	0%
		51-68	14	14	100%	14	0	0%	14	5	36%	14	9	64%	14	2	14%	14	0	0%	14	0	0%	14	0	0%
	Vastus lateralis	20-35	27	11	41%	27	2	7%	26	20	77%	26	1	4%	26	2	8%	26	1	4%	26	0	0%	26	0	0%
		36-50	17	12	71%	17	1	6%	17	8	47%	17	1	6%	17	2	12%	17	0	0%	17	0	0%	17	0	0%
		51-68	11	4	36%	11	0	0%	11	7	64%	11	2	18%	11	0	0%	11	0	0%	11	0	0%	11	0	0%
	Total	20-35	215	69	32%	215	6	3%	187	66	35%	187	19	10%	187	29	16%	187	7	4%	187	6	3%	187	0	0%
		36-50	118	63	53%	117	5	4%	105	37	35%	105	31	30%	105	19	18%	105	4	4%	105	0	0%	105	0	0%
		51-68	85	44	52%	85	2	2%	75	28	37%	75	29	39%	75	18	24%	75	0	0%	75	1	1%	75	0	0%
Right	Gastrocnemius	20-35	33	3	9%	33	0	0%	34	7	21%	34	0	0%	34	2	6%	34	3	9%	34	1	3%	34	0	0%
		36-50	19	0	0%	19	1	5%	19	10	53%	19	0	0%	19	4	21%	19	0	0%	19	0	0%	19	0	0%
		51-68	14	3	21%	14	0	0%	14	4	29%	14	4	29%	14	1	7%	14	0	0%	14	0	0%	14	0	0%
	Iliopsoas	20-35	33	0	0%	33	0	0%	33	7	21%	33	2	6%	33	5	15%	33	3	9%	33	1	3%	33	0	0%
		36-50	15	4	27%	15	1	7%	15	8	53%	15	3	20%	15	6	40%	15	0	0%	15	1	7%	15	0	0%
		51-68	14	4	29%	14	0	0%	14	1	7%	14	4	29%	14	7	50%	14	0	0%	14	0	0%	14	0	0%
	Patellar ligament	20-35	27	10	37%	27	0	0%	28	5	18%	28	0	0%	28	1	4%	28	1	4%	28	0	0%	28	0	0%
		36-50	17	12	71%	17	1	6%	17	4	24%	17	3	18%	17	0	0%	17	2	12%	17	0	0%	17	0	0%
		51-68	14	7	50%	14	1	7%	13	4	31%	13	3	23%	13	1	8%	13	0	0%	13	0	0%	13	0	0%
	Plantar fascia	20-35	32	10	31%	32	0	0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

	36-50	15	12	80%	15	0	0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	51-68	12	10	83%	12	0	0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadriceps femoris	20-35	31	12	39%	31	2	6%	32	14	44%	32	6	19%	32	7	22%	32	0	0%	32	0	0%	32	0	0%
	36-50	17	12	71%	17	1	6%	17	4	24%	17	5	29%	17	2	12%	17	0	0%	17	0	0%	17	0	0%
	51-68	10	8	80%	10	1	10%	10	3	30%	10	4	40%	10	2	20%	10	0	0%	10	0	0%	10	0	0%
Triceps surae	20-35	28	19	68%	28	0	0%	30	5	17%	30	8	27%	30	0	0%	30	0	0%	30	0	0%	30	0	0%
	36-50	18	18	100%	18	0	0%	16	5	31%	16	10	63%	16	1	6%	16	2	13%	16	0	0%	16	0	0%
	51-68	14	13	93%	14	1	7%	14	2	14%	14	9	64%	14	0	0%	14	1	7%	14	0	0%	14	0	0%
Vastus lateralis	20-35	31	10	32%	31	2	6%	31	23	74%	31	1	3%	31	5	16%	31	0	0%	31	0	0%	31	0	0%
	36-50	15	11	73%	15	0	0%	16	6	38%	16	3	19%	16	2	13%	16	0	0%	16	0	0%	16	0	0%
	51-68	8	6	75%	8	0	0%	9	7	78%	9	0	0%	9	0	0%	9	0	0%	9	0	0%	9	0	0%
Total	20-35	215	64	30%	215	4	2%	188	61	32%	188	17	9%	188	20	11%	188	7	4%	188	2	1%	188	0	0%
	36-50	116	69	59%	116	4	3%	100	37	37%	100	24	24%	100	15	15%	100	4	4%	100	1	1%	100	0	0%
	51-68	86	51	59%	86	3	3%	74	21	28%	74	24	32%	74	11	15%	74	1	1%	74	0	0%	74	0	0%

f= frequency, BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.

Appendix 10. General frequencies of entheses in the lower limbs of the NILMFS collection.

			BF (Z1)		ER (Z1)		TC		BF (Z2)		ER (Z2)		FPO		MPO		CA	
Enthesis	**Side**	**Score**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**
Iliopsoas	Right	0	73	71.6	89	87.3	51	50	68	66.7	69	67.6	84	82.4	90	88.2	91	89.2
		1	16	15.7	3	2.9	40	39.2	23	22.5	21	20.6	7	6.9	1	1	0	0
		2	3	2.9	0	0	-	-	0	0	1	1	0	0	0	0	0	0
		NR	10	9.8	10	9.8	11	10.8	11	10.8	11	10.8	11	10.8	11	10.8	11	10.8
	Left	0	75	73.5	91	89.2	48	47.1	72	70.6	65	63.7	92	90.2	92	90.2	95	93.1
		1	18	17.6	4	3.9	47	46.1	22	21.6	28	27.5	3	2.9	3	2.9	0	0
		2	2	2	0	0	-	-	1	1	2	2	0	0	0	0	0	0
		NR	7	6.9	7	6.9	7	6.9	7	6.9	7	6.9	7	6.9	7	6.9	7	6.9
Gastrocnemius	Right	0	87	85.3	93	91.2	83	81.4	83	81.4	84	82.4	93	91.2	95	93.1	96	94.1
		1	8	7.8	3	2.9	13	12.7	12	11.8	11	10.8	3	2.9	1	1	0	0
		2	1	1	0	0	-	-	1	1	1	1	0	0	0	0	0	0
		NR	6	5.9	6	5.9	6	5.9	6	5.9	6	5.9	6	5.9	6	5.9	6	5.9
	Left	0	87	85.3	90	88.2	69	67.6	86	84.3	68	66.7	88	86.3	93	91.2	92	90.2
		1	6	5.9	4	3.9	24	23.5	7	6.9	23	22.5	5	4.9	0	0	1	1
		2	1	1	0	0	-	-	0	0	2	2	0	0	0	0	0	0
		NR	8	7.8	8	7.8	9	8.8	9	8.8	9	8.8	9	8.8	9	8.8	9	8.8
Quadriceps femoris	Right	0	44	43.1	80	78.4	62	60.8	60	58.8	79	77.5	81	79.4	82	80.4	83	81.4
		1	40	39.2	4	3.9	21	20.6	23	22.5	4	3.9	2	2	1	1	0	0
		2	0	0	0	0	-	-	0	0	0	0	0	0	0	0	0	0
		NR	18	17.6	18	17.6	19	18.6	19	18.6	19	18.6	19	18.6	19	18.6	19	18.6
	Left	0	46	45.1	87	85.3	72	70.6	64	62.7	80	78.4	88	86.3	89	87.3	89	87.3
		1	42	41.2	2	2	17	16.7	25	24.5	9	8.8	1	1	0	0	0	0
		2	1	1	0	0	-	-	0	0	0	0	0	0	0	0	0	0
		NR	13	12.7	13	12.7	13	12.7	13	12.7	13	12.7	13	12.7	13	12.7	13	12.7
Vastus lateralis	Right	0	38	37.3	79	77.5	32	31.4	68	66.7	74	72.5	80	78.4	80	78.4	80	78.4
		1	42	41.2	1	1	48	47.1	12	11.8	6	5.9	0	0	0	0	0	0
		2	0	0	0	0	-	-	0	0	0	0	0	0	0	0	0	0
		NR	22	21.6	22	21.6	22	21.6	22	21.6	22	21.6	22	21.6	22	21.6	22	21.6
	Left	0	44	43.1	84	82.4	34	33.3	73	71.6	81	79.4	81	79.4	83	81.4	83	81.4
		1	39	38.2	0	0	49	48	10	9.8	1	1	2	2	0	0	0	0
		2	2	2	1	1	-	-	0	0	1	1	0	0	0	0	0	0
		NR	17	16.7	17	16.7	19	18.6	19	18.6	19	18.6	19	18.6	19	18.6	19	18.6
Patellar ligament	Right	0	44	43.1	86	84.3	71	69.6	76	74.5	85	83.3	86	84.3	93	91.2	93	91.2
		1	50	49	10	9.8	22	21.6	17	16.7	7	6.9	6	5.9	0	0	0	0
		2	2	2	0	0	-	-	0	0	1	1	1	1	0	0	0	0
		NR	6	5.9	6	5.9	9	8.8	9	8.8	9	8.8	9	8.8	9	8.8	9	8.8
	Left	0	39	38.2	83	81.4	62	60.8	72	70.6	84	82.4	80	78.4	86	84.3	89	87.3
		1	53	52	10	9.8	27	26.5	17	16.7	5	4.9	9	8.8	3	2.9	0	0
		2	2	2	1	1	-	-	0	0	0	0	0	0	0	0	0	0
		NR	8	7.8	8	7.8	13	12.7	13	12.7	13	12.7	13	12.7	13	12.7	13	12.7
Triceps surae	Right	0	20	19.6	88	86.3	86	84.3	62	60.8	85	83.3	79	77.5	88	86.3	94	92.2
		1	68	66.7	9	8.8	9	8.8	33	32.4	10	9.8	14	13.7	7	6.9	1	1
		2	9	8.8	0	0	-	-	0	0	0	0	2	2	0	0	0	0
		NR	5	4.9	5	4.9	7	6.9	7	6.9	7	6.9	7	6.9	7	6.9	7	6.9
	Left	0	16	15.7	86	84.3	81	79.4	64	62.7	86	84.3	75	73.5	86	84.3	91	89.2
		1	71	69.6	7	6.9	10	9.8	27	26.5	5	4.9	13	12.7	5	4.9	0	0
		2	6	5.9	0	0	-	-	0	0	0	0	3	2.9	0	0	0	0
		NR	9	8.8	9	8.8	11	10.8	11	10.8	11	10.8	11	10.8	11	10.8	11	10.8
Plantar Fascia	Right	0	59	57.8	94	92.2	-	-	-	-	-	-	-	-	-	-	-	-
		1	33	32.4	2	2	-	-	-	-	-	-	-	-	-	-	-	-
		2	4	3.9	0	0	-	-	-	-	-	-	-	-	-	-	-	-
		NR	6	5.9	6	5.9	-	-	-	-	-	-	-	-	-	-	-	-

Left	0	61	59.8	97	95.1	-	-	-	-	-	-	-	-	-	-	-	-
	1	30	29.4	1	1	-	-	-	-	-	-	-	-	-	-	-	-
	2	7	6.9	0	0	-	-	-	-	-	-	-	-	-	-	-	-
	NR	4	3.9	4	3.9	-	-	-	-	-	-	-	-	-	-	-	-

f= frequency, NR= no recordable, BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.

Appendix 11. Presence of EC in the entheses of the lower limbs of the NILMFS skeletal collection by age ranges and side.

		Age	BF (Z1)			ER (Z1)			TC			BF (Z2)			ER (Z2)			FPO			MPO			CA		
Side	**Enthesis**	**range**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**	**N**	***f***	**%**
Left	Gastrocnemius	20-35	2	6%	33	0	0%	33	10	31%	32	1	3%	32	8	25%	32	1	3%	32	0	0%	32	0	0%	32
		36-50	1	3%	29	2	7%	29	5	17%	29	2	7%	29	8	28%	29	3	10%	29	0	0%	29	0	0%	29
		50-65	4	13%	32	2	6%	32	9	28%	32	4	13%	32	9	28%	32	1	3%	32	0	0%	32	1	3%	32
		Total	7	7%	94	4	4%	94	24	26%	93	7	8%	93	25	27%	93	5	5%	93	0	0%	93	1	1%	93
	Iliopsoas	20-35	5	16%	32	1	3%	32	7	22%	32	2	6%	32	11	34%	32	3	9%	32	0	0%	32	0	0%	32
		36-50	5	16%	32	0	0%	32	19	59%	32	5	16%	32	7	22%	32	0	0%	32	1	3%	32	0	0%	32
		50-65	10	32%	31	3	10%	31	21	68%	31	16	52%	31	12	39%	31	0	0%	31	2	6%	31	0	0%	31
		Total	20	21%	95	4	4%	95	47	49%	95	23	24%	95	30	32%	95	3	3%	95	3	3%	95	0	0%	95
	Patellar ligament	20-35	11	31%	35	1	3%	35	4	12%	33	3	9%	33	2	6%	33	5	15%	33	0	0%	33	0	0%	33
		36-50	22	79%	28	2	7%	28	10	38%	26	4	15%	26	0	0%	26	3	12%	26	1	4%	26	0	0%	26
		50-65	22	71%	31	8	26%	31	13	43%	30	10	33%	30	3	10%	30	1	3%	30	2	7%	30	0	0%	30
		Total	55	59%	94	11	12%	94	27	30%	89	17	19%	89	5	6%	89	9	10%	89	3	3%	89	0	0%	89
	Plantar fascia	20-35	7	21%	33	0	0%	33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		36-50	13	38%	34	1	3%	34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		50-65	17	55%	31	0	0%	31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Total	37	38%	98	1	1%	98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Quadriceps femoris	20-35	9	28%	32	1	3%	32	9	28%	32	5	16%	32	5	16%	32	0	0%	32	0	0%	32	0	0%	32
		36-50	13	52%	25	1	4%	25	3	12%	25	11	44%	25	2	8%	25	0	0%	25	0	0%	25	0	0%	25
		50-65	21	66%	32	0	0%	32	5	16%	32	9	28%	32	2	6%	32	1	3%	32	0	0%	32	0	0%	32
		Total	43	48%	89	2	2%	89	17	19%	89	25	28%	89	9	10%	89	1	1%	89	0	0%	89	0	0%	89
	Triceps surae	20-35	21	68%	31	3	10%	31	5	16%	31	3	10%	31	1	3%	31	4	13%	31	3	10%	31	0	0%	31
		36-50	30	94%	32	2	6%	32	2	6%	31	12	39%	31	3	10%	31	10	32%	31	1	3%	31	0	0%	31
		50-65	26	87%	30	2	7%	30	3	10%	29	12	41%	29	1	3%	29	2	7%	29	1	3%	29	0	0%	29
		Total	77	83%	93	7	8%	93	10	11%	91	27	30%	91	5	5%	91	16	18%	91	5	5%	91	0	0%	91
	Vastus lateralis	20-35	8	28%	29	1	3%	29	17	61%	28	4	14%	28	0	0%	28	2	7%	28	0	0%	28	0	0%	28
		36-50	14	56%	25	0	0%	25	16	64%	25	3	12%	25	0	0%	25	0	0%	25	0	0%	25	0	0%	25
		50-65	19	61%	31	0	0%	31	16	53%	30	3	10%	30	2	7%	30	0	0%	30	0	0%	30	0	0%	30
		Total	41	48%	85	1	1%	85	49	59%	83	10	12%	83	2	2%	83	2	2%	83	0	0%	83	0	0%	83
	Total	20-35	63	28%	225	7	3%	225	52	28%	188	18	10%	188	27	14%	188	15	8%	188	3	2%	188	0	0%	188
		36-50	98	48%	205	8	4%	205	55	33%	168	37	22%	168	20	12%	168	16	10%	168	3	2%	168	0	0%	168
		50-65	119	55%	218	15	7%	218	67	36%	184	54	29%	184	29	16%	184	5	3%	184	5	3%	184	1	1%	184
		Total	280	43%	648	30	5%	648	174	32%	540	109	20%	540	76	14%	540	36	7%	540	11	2%	540	1	0%	540

Right	Gastrocnemius	20-35	0	0%	33	0	0%	33	5	15%	33	3	9%	33	2	6%	33	2	6%	33	0	0%	33	0	0%	33
		36-50	2	6%	31	1	3%	31	2	6%	31	2	6%	31	4	13%	31	1	3%	31	0	0%	31	0	0%	31
		50-65	7	22%	32	2	6%	32	6	19%	32	8	25%	32	6	19%	32	0	0%	32	1	3%	32	0	0%	32
		Total	9	9%	96	3	3%	96	13	14%	96	13	14%	96	12	13%	96	3	3%	96	1	1%	96	0	0%	96
	Iliopsoas	20-35	4	13%	32	0	0%	32	8	26%	31	3	10%	31	5	16%	31	5	16%	31	0	0%	31	0	0%	31
		36-50	4	13%	31	0	0%	31	15	48%	31	6	19%	31	7	23%	31	1	3%	31	0	0%	31	0	0%	31
		50-65	11	38%	29	3	10%	29	17	59%	29	14	48%	29	10	34%	29	1	3%	29	1	3%	29	0	0%	29
		Total	19	21%	92	3	3%	92	40	44%	91	23	25%	91	22	24%	91	7	8%	91	1	1%	91	0	0%	91
	Patellar ligament	20-35	12	35%	34	2	6%	34	4	12%	33	3	9%	33	1	3%	33	2	6%	33	0	0%	33	0	0%	33
		36-50	21	68%	31	3	10%	31	5	17%	29	6	21%	29	1	3%	29	4	14%	29	0	0%	29	0	0%	29
		50-65	19	61%	31	5	16%	31	13	42%	31	8	26%	31	6	19%	31	1	3%	31	0	0%	31	0	0%	31
		Total	52	54%	96	10	10%	96	22	24%	93	17	18%	93	8	9%	93	7	8%	93	0	0%	93	0	0%	93
	Plantar fascia	20-35	6	17%	35	0	0%	35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		36-50	15	47%	32	2	6%	32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		50-65	16	55%	29	0	0%	29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Total	37	39%	96	2	2%	96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Quadriceps femoris	20-35	5	18%	28	2	7%	28	9	32%	28	4	14%	28	0	0%	28	1	4%	28	0	0%	28	0	0%	28
		36-50	16	62%	26	2	8%	26	5	19%	26	9	35%	26	0	0%	26	0	0%	26	0	0%	26	0	0%	26
		50-65	19	63%	30	0	0%	30	7	24%	29	10	34%	29	4	14%	29	1	3%	29	1	3%	29	0	0%	29
		Total	40	48%	84	4	5%	84	21	25%	83	23	28%	83	4	5%	83	2	2%	83	1	1%	83	0	0%	83
	Triceps surae	20-35	24	67%	36	4	11%	36	3	8%	36	3	8%	36	4	11%	36	6	17%	36	5	14%	36	0	0%	36
		36-50	28	90%	31	2	6%	31	2	7%	30	14	47%	30	3	10%	30	8	27%	30	2	7%	30	1	3%	30
		50-65	25	83%	30	3	10%	30	4	14%	29	16	55%	29	3	10%	29	2	7%	29	0	0%	29	0	0%	29
		Total	77	79%	97	9	9%	97	9	9%	95	33	35%	95	10	11%	95	16	17%	95	7	7%	95	1	1%	95
	Vastus lateralis	20-35	10	37%	27	1	4%	27	15	56%	27	4	15%	27	1	4%	27	0	0%	27	0	0%	27	0	0%	27
		36-50	15	60%	25	0	0%	25	18	72%	25	3	12%	25	2	8%	25	0	0%	25	0	0%	25	0	0%	25
		50-65	17	61%	28	0	0%	28	15	54%	28	5	18%	28	3	11%	28	0	0%	28	0	0%	28	0	0%	28
		Total	42	53%	80	1	1%	80	48	60%	80	12	15%	80	6	8%	80	0	0%	80	0	0%	80	0	0%	80
	Total	20-35	61	27%	225	9	4%	225	44	23%	188	20	11%	188	13	7%	188	16	9%	188	5	3%	188	0	0%	188
		36-50	101	49%	207	10	5%	207	47	27%	172	40	23%	172	17	10%	172	14	8%	172	2	1%	172	1	1%	172
		50-65	114	55%	209	13	6%	209	62	35%	178	61	34%	178	32	18%	178	5	3%	178	3	2%	178	0	0%	178
		Total	276	43%	641	32	5%	641	153	28%	538	121	22%	538	62	12%	538	35	7%	538	10	2%	538	1	0%	538

f= frequency, BF(Z1)= bone formation in zone 1, ER(Z1)= erosion in zone 1, TC= textural change, BF(Z2)= bone formation in zone 2, ER(Z2)= erosion in zone 2, FPO= fine porosity, MPO= macro-porosity, CA= cavitation.