MATTEO MARESCOTTI

THE DYNAMIC VALGUM KNEE IN FEMALE VOLLEYBALL PLAYERS: STRUCTURE AND FUNCTION RELATION

VOLUME 1

Dissertation in the scope of the Master in Biokinetics, supervised by Ph D. Ana Faro and Ph D Beatriz Gomes, submitted to the Faculty of Sport Sciences and Physical Education of the University of Coimbra.

SEPTEMBER 2019

AKNOWLEDGMENT

I would like to thank several people that unroll an important role in the developing of this work.

First of all I would like to thank the Professor Ana Faro, which not only have introduce me to the reality of the university of Coimbra, but also have helped me in several occassions and especially in this thesis devlopment. A special thanks to the Professor Beatriz Gomes, who unrolled an important role not only with her suggestions but especially for the practice development of this thesis.

A special thank is for my family and my fiancee that have supported me, despite the distance, in this wonderfull experience. Here in Coimbra I met several people and I would like to say a big Obrigado especially to the Academica de Coimbra volleyball university team, the Lousa voleiclube and all of my erasmus friends (Rua Saragoça 11).

Last I would like to thank my first housemate Gregorio who is more than a friend and thanks to our meeting all of this has been possible.

Abstract

PURPOSE: The main purpose was to verify the relation between the theory enhounced by Thomas Myers (Myers 2014),the regional interdependence enhounced by Gray Cook (Cook, 2010b; Cook et al., 1998) and the biomechanic risk factors of the ACL rupture such as the dynamic valgum knee and the landing stress, in volleyball female athletes. In relation to the antropometric it has been studied which of the antropometric measurment could be related to the ACL rupture risk factors. Another purpose was to point out the relation between a general movement as the single leg squat and a specific volleyball technique as the volleyball landing. this aim could be relevant according to some new approach of the sport science which researched the specificty both for the prevention and for the performance. Finally this thesis aimed to define if the FMS is a suitable test to detect ACL rupture risk factors.

METHODOLOGY: 23 females volleyball players, aged between 12 and 17 years old (14.35 ± 1.53 years old) without any previous knee's injury, were analysed considering the following variables: i) anthropometric and general information; ii) quality of movement (the functional movement screen score system by Gray Cook (Cook, 2010a; Cook, Burton, Fields, & Kiesel, 1998), and the flexibility through the sit and reach) iii) biomechanical characeristics(the dynamic valgum knee index by Scholtes and Salsich (Scholtes & Salsich, 2017), derived by the single leg squat's video analysis using tracker software for data collection and the ground forces at landing measured by kistler force platform).The mean and the standard deviation of the variables were calculated. Furthermore all data (flexibility, FMS score and dynamic valgum knee index) were analyzed through a correlation matrix using the pearson correlation coefficient (considering significant $p \leq 0.05$).

RESULTS: The sit and reach (back superficial line) test showed no correlation with the other variables. The relation between the sit and reach score and the ground forces at landing was also weak. The FMS total score correlated with the hip angle ($R= .576$ $p \leq 0.01$) and with the knee's angle ($R= .555$ $p \leq 0.01$) made the FMS protocol a reliable test for the dynamic valgum index. The possible relation between two far part of the body (regional interdependence) was confirmed by the inverted relation between reaching right and dynamic valgum knee ($R= .422$ $p \leq 0.05$). The variables (years, years of practice and hours a week) do not present any correlation with the other variables.

CONCLUSION: The relation between the superficial back line pre-stress and the dynamic valgum knee index was not statistically significant. The FMS score provided possible informations about the hip and the knee uncorrect pattern (excessive dynamic valgum knee and excessive hip displacement). The FMS score seems to be a suitable indicator for the dynamic Valgum index , hip

(R= .576 p ≤ 0.01) and knee (R= .555 p ≤ 0.01). The present results are in accordance to previous studies which state the link between uncorrect pattern of movement in no continuos body areas(shoulder-knee relation), according to the regional interdependence

Keywords: female young athlete, volleyball, connective tissue, flexibility, FMS score, dynamic valgum knee index, ground forces.

Resumo

OBJETIVO: O principal objetivo foi verificar a relação entre a teoria enunciada por Thomas Myers (Myers 2014), a interdependência regional enunciada por Gray Cook (Cook, 2010b; Cook et al., 1998) e os fatores de risco biomecânicos da ruptura do LCA. como o joelho valgum dinâmico e o estresse de aterrissagem, em atletas de voleibol. Em relação à antropometria, estudou-se qual das medidas antropométricas poderia estar relacionada aos fatores de risco de ruptura do LCA. Outro objetivo foi apontar a relação entre um movimento geral como agachamento unipodal e uma técnica específica de vôlei como aterrissagem. esse objetivo pode ser relevante de acordo com alguma nova abordagem da ciência do esporte que pesquisou as especificidades tanto para a prevenção quanto para o desempenho. Finalmente, esta tese teve como objetivo definir se o SFM é um teste adequado para detectar fatores de risco de ruptura do LCA.

METODOLOGIA: Foram analisadas 23 jogadoras de voleibol do sexo feminino, com idades entre 12 e 17 anos (14,35 ± 1,53 anos) sem lesão anterior do joelho, considerando as seguintes variáveis: i) informações antropométricas e gerais; ii) qualidade do movimento (o sistema funcional de pontuação da tela de movimento de Gray Cook (Cook, 2010a; Cook, Burton, Fields e Kiesel, 1998) e a flexibilidade através do sentar e alcançar) iii) características biomecânicas (joelho do valgo dinâmico) O índice de Scholtes e Salsich (Scholtes & Salsich, 2017), obtido pela análise de vídeo do agachamento unipodal usando software tracker para coleta de dados e as forças terrestres no pouso medidas pela plataforma de força de Kistler). calculado. Além disso, todos os dados (flexibilidade, escore FMS e índice dinâmico do joelho em valgo) foram analisados por meio de uma matriz de correlação utilizando o coeficiente de correlação de Pearson (considerando significante $p \leq 0,05$).

RESULTADOS: O teste de sentar e alcançar (linha superficial posterior) não mostrou correlação com as demais variáveis. A relação entre a pontuação de sentar e alcançar e as forças de terra no pouso também foi fraca. A pontuação total da FMS correlacionou-se com o ângulo do quadril ($R = 0,576$ $p \leq 0,01$) e com o ângulo do joelho ($R = 0,555$ $p \leq 0,01$) tornou o protocolo da FMS um teste confiável para o índice de valgo dinâmico. A possível relação entre duas partes distantes do corpo (interdependência regional) foi confirmada pela relação invertida entre alcançar o joelho valgum direito e dinâmico ($R = 0,422$ $p \leq 0,05$). As variáveis (anos, anos de prática e horas por semana) não apresentam correlação com as demais variáveis.

CONCLUSÃO: A relação entre o pré-estresse superficial da linha de trás e o índice dinâmico do joelho em valgo não foi estatisticamente significante. O escore FMS forneceu informações possíveis sobre o padrão incorreto do quadril e do joelho (joelho valgum dinâmico excessivo e deslocamento excessivo do quadril). O escore FMS parece ser um indicador adequado para o índice dinâmico de Valgum, quadril ($R = 0{,}576$ $p \leq 0{,}01$) e joelho ($R = 0{,}555$ $p \leq 0{,}01$)). Os presentes resultados estão de acordo com estudos anteriores que afirmam a ligação entre padrão incorreto de movimento em áreas corporais não contínuas (relação ombro-joelho), de acordo com a interdependência regional.

Palavras-chave: atleta jovem, vôlei, tecido conjuntivo, flexibilidade, pontuação na FMS, índice dinâmico de joelho em valgo, forças terrestres

GENERAL INDEX:

Chapter 1: Introduction

Chapter 2: Literature Review

Chapter 3: Methods

Chapter 4: Results

Chapter 5: Discussion

Chapter 6: Conclusions

REFERENCES

APPENDIX.

INDEX OF TABLES

INDEX OF FIGURES

ABBREVIATION LIST:

ACL: Anterior Cruciate Ligament

FMS: Functional Movement Screen

cm: Centimeter

kg: Kilogramm

°: Degree

N: Newton

Pt: Point

s: Second

.

CHAPTER 1
INTRODUCTION

1.1 **Introduction**

The knee is one of the most important joints of the human body, this is a gliding joint, that allows flexion-extension and limited internal and external rotation; the cartilagenous structures and the ligaments stabylize the knee allowing to develop several correct motor patterns for the sport performance as for the all-day life. The acyclic sport practices tha consist in alterning side stepping, jump and landing cycle, induces stress on the structure (Mehl et al., 2018; Savage, Lay, Wills, Lloyd, & Doyle, 2018). Among all the injuries, one of the most relevant is the anterior cruciate ligament rupture (ACL), whose recovery is one of the longest and complicated with an high recidivism (Laboute et al., 2010; Salmon et al., 2018). Epidemyological studies show that this injury has a sort of female predominance which start since the young sport categories (Beynnon et al., 2014; Stanley, Kerr, Dompier, & Padua, 2016), confering to anatomical and hormonal features this phenomen. The anterior cruciate ligament rupture is caused by 3 movements: i) excessive tibial intrarotation associated with varum knee, ii) excessive tibial extrarotation associated with valgum knee and iii) knee hyperextension. These abnormal movement could happen in 2 forms: contact and no contact. The science of sport retains the no contact the predominant (Hewett, Ford, & Myer, 2006), confering to the athletic and physical training the important aim of preventing this injury. One of the most common risk factors of the ACL rupture is the ligamentous one, known as dynamic valgum knee. This pattern consists in a temporary valgum attitude, which is a common strategy for achieving a correct sport technique.

The adaptations induced by the sport practice are universal and they could involve the connective tissue, as confirmed by several studies which confer to this tissue a great adaptive capacity thanks to the fibroblast action (Checa, Rausch, Petersen, Kuhl, & Duda, 2015; Donald E. Ingber, Wang, & Stamenović, 2014; Piancino et al., 2017) The fibroblast is the functional unit of the connective tissue and it is a part of a sensibility which is known as mechanotrasduction, and consist on the capacity of modify the connective tissue according to the mechanical stress perceived (D. E. Ingber, 2003b, 2003a) .

The microbiology of the connective tissue is one of the biological basements of the holistical theories. One of these theories is the one that Thomas Myers has described in his book ("Anatomy Trains, Myofascial Meridians for Manual and Movement Therapists, 3rd Edition" Thomas Myers, 2014 Churchill Livingstone**)** consisting of 9 myofascial trains that links the human body conferring to it tensegrity.

Three of the 9 myofascial lines, the superficial back line, the functional back line and the frontal back line were confirmed by part of the literature (Jan Wilke, Krause, Vogt, & Banzer, 2016). The superficial back line is a myoconnective continuity that links on the back part the head to the feet; some of the "stations" of this line are the ischiocrural and paravertebral muscles. Considering the anatomic insertions of the muscles which compose the superficial back line, this thesis intends to analyse if there could be a relation between the back superficial line and an uncorrect pattern, as the dynamic valgum knee.

Resuming some of the most important definiton of training (sport or fitness) could be defined as a series of movements that want to induce function and structure adaptations in the human system. Recently a part of the scientific movement community started to use several protocol to understand the quality of the movements; one of this is the protocol, named FMS score, proposed by Gray Cook (Cook, 2010b; Cook et al., 1998). Gray Cook explained that the human movement is the sum of several segment interaction and every part can influence the other. This concept, known as regional interdependence, is the base of all the Gray Cook's statements.

1.2 Personal motivation

The movement is a complex phenomen that induce several adaptations on a subject, following this concept the sport science has derivated the concept of training. Through the sport training an athlete tries to modify his structures and functions to be more performing. The performance research lead to a fast adaptations which lot of times is opposite to an healthy idea of learning movement. This idea bases on the proximal stability whereas most of the sport gesture provides for a very "dystalizated" learning (Cook, 2010b), this idea can partially explain an uncorrect movement pattern but since a couple of years the movement science has started linking function and structure focusing on a possible relation between these two features. For several years a part of the science has described the human structure only as a "dead "container but focusing on the "deepest level", the microbiology, the reality is completely different: the human structure, composed at most of connective tissue is a complex world. Reported by Ingber (D. E. Ingber, 2003a, 2003b; D E Ingber, 1993) one of the key to understand the complexity of the structure is the mechanotrasduction. This feature strongly associate structure and fuction since mechanotrasduction explains that the adaptation of the structure are consequences of the function. These microbiological aspects are the basements of the Thomas Myers theories, which define 9 lines in the human body, each of this line is the sequence of some part of the body, according to the Myers' theories (2014) on this line the tension is spread in so creating a continuity. Reading all of these theories has induced me to change my point of view, so I have tried to link them in the activity which I have most explored in my life, both as athlete and as coach, the volleyball. In my thesis I want to anlyze every adaptation that the volleyball training could induce on the volleyball player, without limiting only to a single understanding but link every features of a motor pattern.

The exploration of new ideas and especially of a new point of view is the base for a constant and consistent improving. Considering my practice I have tought that the compreension of the abovementioned aspects, could help me to reduce the injury of my volleyball athletes.

After having some discussion with coaches and considering the literature I have realized that the ACL rupture is the nº1 danger for the athletes' carreer. On one hand the concepts reported in this literature review seems "light years away" far from my all-day training, on the other hand a critical and a scientific view could easy observe these complexes basements. Analysing a volleyball player sample I intend to analyze the relations between biomechanical characteristics (hip and knee movements through a single leg squat videoanalysis, ground forces through a force platform) quality of movement features (sit and reach- FMS score).

1.3 Purpose of the study

1.3.1Main purpose

The main purpose was to verify the relation between the theory enhounced by Thomas Myers (Myers 2014 ,),the regional interdependence enhounced by Gray Cook (Cook, 2010b; Cook et al., 1998) and the biomechanic risk factors of the ACL rupture such as the dynamic valgum knee and the landing stress, in volleyball female athletes.

1.3.2 Secondary purposes.

In relation to the antropometric it has been studied which of the antropometric measurment could be related to the ACL rupture risk factors. Another purpose was to point out the relation between a general movement as the single leg squat and a specific volleyball technique as the volleyball landing. this aim could be relevant according to some new approach of the sport science which researched the specificty both for the prevention and for the performance. Finally this thesis aimed to define if the FMS is a suitable test to detect ACL rupture risk factors.

CHAPTER 2
LITERATURE REVIEW

Introduction.

The literature review is composed of different sections. In the first one then to a knee's biomechanical and anatomical overwiew , there is a description of the key factors of the ACL rupture, the second one deals with the integrated system and it fast resumes the Gray Cook researches about the movement, the third one reports a brief mention on the connective tissue properties, usefull to explain the link between structure and function, and especially it deepens the Myofascial Trains theory by Thomas Myers (2014).

2.1 The Knee

2.1.1 Structure and function knee's descripiton.

The knee is the intermediate articulation of the lower limb, it allows primary and secondary movement: flexion- extension (transversal axes), rotation when the knee assumes a flexed position (longitudinal axes). The mechanical request has two specific and complicated goals: great stabilty in the complete extension, opposing to the cut force due to the torque amplitude and the body weight, great mobility in flexion in order to achieve an optimal walking pattern.

Due to the bone's conformation the femoral axes and the lower leg axes defines a 170-175° external angle, known as physiologic valgum. This anatomical characteristic presents difference in relation to the sex: in the women population, due to the different pelvis conformation, is wider. Anyway this condition induces a closer knee angle and shows the subject with the typical "x position" leg, this anatomical profile is known as pathological valgum. The other knee's lateral deviation is known as varum knee and it implies the opposite attitude; both of these abnormal conditions negatively influence the bone development: the main patology associated with a pathological knee is the artrosis, on the other hand an uncorrect knee's attitude can afflict other structures. The valgum physiological orientation is a consequence of the application of the femoral force, this is a mixed one and it can be composed in two components a vertical and a trasversal one: this last push the knee to the inside;

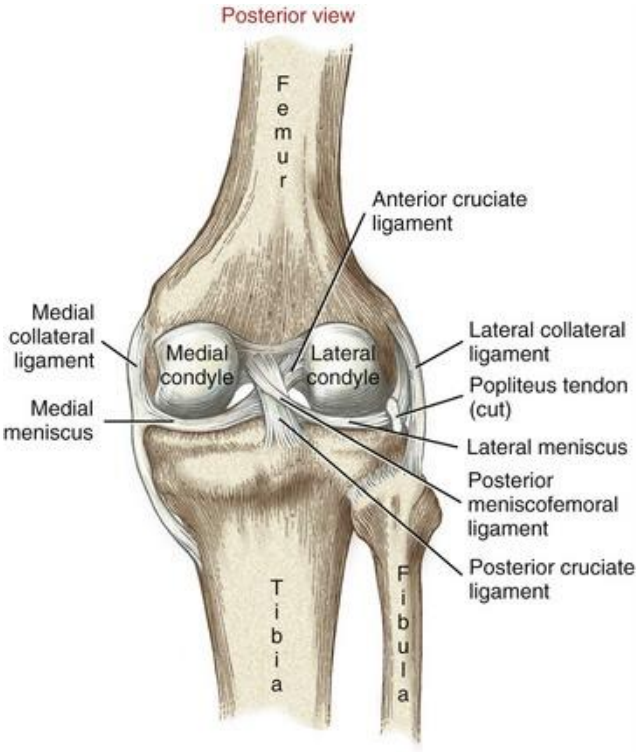

Figure 1. Anatomic knee's structure: ligaments and joint. From https://clinicalgate.com/knee-5/ .

The figure 1 shows t the knee presents a system that opposes to this force, stabylising the articulation, the main ligaments of this system are the two collateral ligaments and the two cruciate ligaments: fibular collateral ligament: 276kg/cm2 force resistence and deformable at 19% and the tybial collateral ligament 115 kg/cm2 force resistent and deformable at 12,5%.

In the knee there are two other ligaments known as cruciates, which are in the intercondylea fossa into the articular capsule out of the synovial membrane. The anterior cruciate ligament is composed of three different bandages that link the tibia beetween the 2 meniscus and the assial part of the exterior condyle of the femoris, the direction is up and external, the posterior cruciate ligament is composed of three different bandages, up and internal oriented that link the meniscus's posterior part and the intercondyle notch.

Both cruciates ligament are responsable at main of the knee's stability: the muscle intervetion is effective especially in movement with low functional request (Sharifi, Shirazi-Adl, & Marouane, 2017). During the flexion and extension the tybia move in different ways: during the extension an anterior slippage of the tibial surface happens,wheras during the flexion, the tibial slippage is posterior.

The cruciate ligaments exert their action, preserving the correct articular relation between femoris and tybia. The trasversal force application afflict the knee stability: acute: inducing a damage to the structure or chronical: the knee assume the valgum or varum adaptation.(A. I. Kapandji, 2011).

2.1.2 Female risk factors for knee injuries.

The knee injuries are typical negative events that happen during every level sport competition, this kind of event is very common and it has negative effect on the athlete's total health; some epydemiological studies revealed that the main one is the anterior cruciate ligament rupture; this is typical of the female (Beynnon et al., 2014; Stanley et al., 2016), younger than 20 years and older than 40 (Mall et al., 2014), this younger trend of the last 20 could be the consequence of the higher partecipation and high competition level in young age: the high intensity and high volume of training rise the number of children and adolescent afflicted by this pathology.

The female population presents more intrinsical factors than the boy,due to different anthropometrical and hormonal profile, repeated scientific analysis have shown as a female population presents several anatomical conditions, as the pelvi amplitude and anteversion, which induce higher peak valgum and higher sidecutting force on the knee during a dynamic pattern (Hewett, Ford, et al., 2006; Howard, Fazio, Mattacola, Uhl, & Jacobs, 2011; LaBella, Hennrikus, & Hewett, 2014; Nguyen & Shultz, 2009).

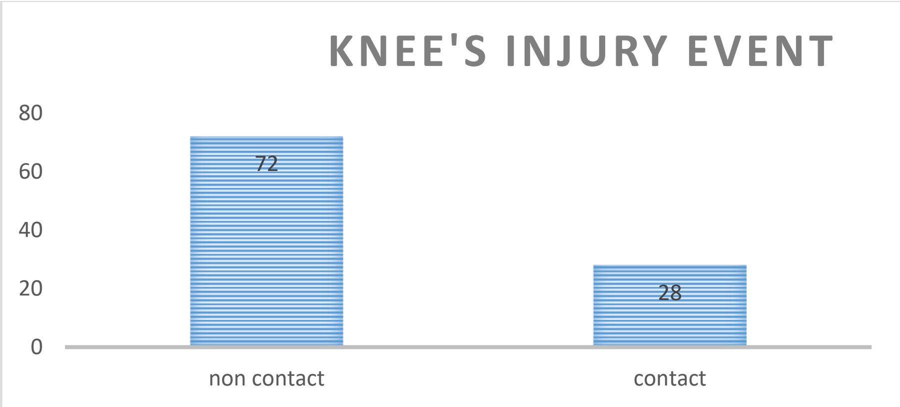

Figure 2. The no contact dynamic is the most common inducing the ACL rupture adapted from Hewett, Ford, & Myer, 2006.

The correct load balance is an important prevention form for the ACL. rupture, this fact is confirmed by the fact that the injury considerely happens in a non contact situation as reported in the figure 2 (Hewett, Ford, & Myer, 2006;)

Indepedently of contact or non contact dynamics; the anterior cruciate ligament rupture is the consequence of three different uncorect movements: an excessive tybial intrarotation associated with varum knee, an excessive tybial extrarotation associated with valgum knee,a knee hyperextension.

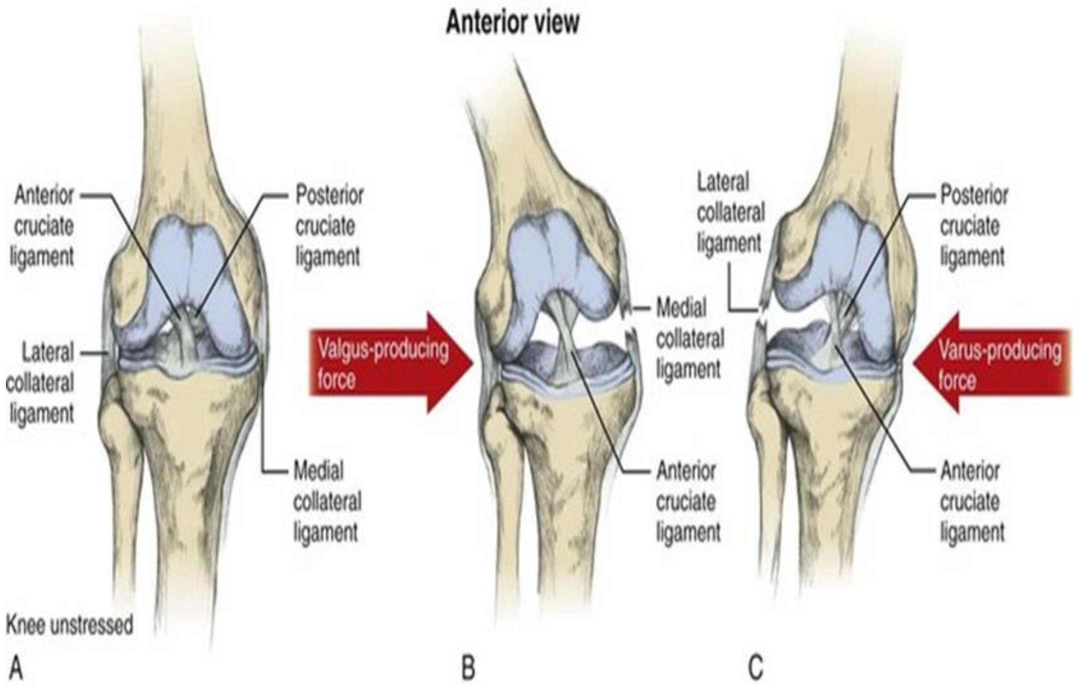

Figure 3. The knee and the excessive forces that can stress the ligamentouses structures from https://www.braceaccess.com/best-knee-braces-mcl-injuries/

The figure 3 shows the force that can damage the knee's stability and how the anterior cruciate ligament injury is associated with the collateral rupture; furthermore the anterior cruciate ligament total rupture is offen associated with lesions to the medial meniscus and the medial collateral known as the terrible triad, with a dramatic decadence in the athletics and life condition.

During the sport activity, there are several conditions attributable to the anterior cruciate ligament's etiology: the sudden change of direction associated with continuos deceleration-acceleration cycle and the landing create cut force that can afflict the knee's health. Sport practising is a condition that can be considered as a risk factor for the knee; analysing 721 young athlete male and female practicing soccer, volley and basketball mean age 13,8 ± 2,2 mean weight 53,9 kg ± 12,3mean height 159,4 cm ± 8,2 it has been established different conditions (Hewett, 2017; Myer Gregory D, Brent CSCS, Ford Kevin R, & Hewett Timothy E, 2011):

The first was no risk factors . The second was the quadriceps prevalence: highlighted by a weak knee flexion caused probably by a unsufficient ratio between anterior and posterior upper leg muscle. The third was the ligamentous deficit: highlighted by a macroscopic dynamic valgum knee probably caused by an uncorrect pattern of movement. The fourth, the trunk deficit: highlighted by an excessive and uncontrolled trunk hip movement as lateral flexion and rotation, probably caused by an unefficent control on the trunk and hip muscles. The leg deficit: Ford et al.has defined it as a different recruiment and strenght between the two lower limb (Myer Gregory D et al. 2011)

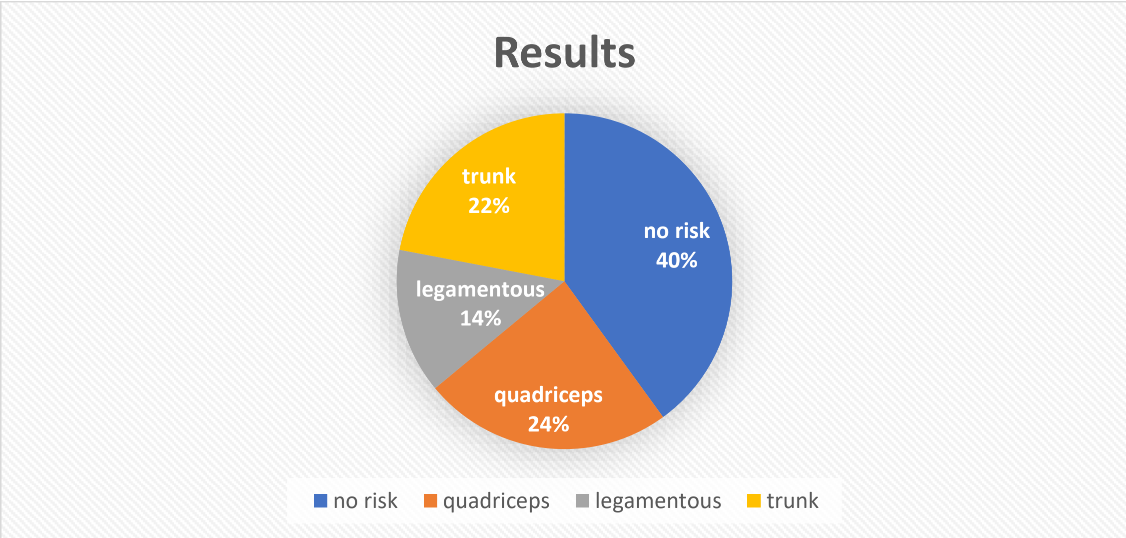

Figure 4. The distribution of the risk factor of the anterior cruciate ligament rupture in a female population . Adapted from Myer et al. 2011

The study confirm that the female population is the more afflicted by risk factor: Figure 4 about the female population, was analysed in the previous research, and shows that the 60% percent presents one risk factor of anterior cruciate rupture (Myer et al. 2011), moreover the ligamentous condition is offen associated to the other two dangerous conditions (trunk and quadriceps)

The anterior cruciate ligament rupture is a consequence of several factor that can be grouped as: structural such as ligamentous lassity and bond morphology, or environmental such as repeated training and weak neuromuscular control. These 2 conditions are mixed and although it is not possible to easy modify by training the structural part, it is possible improving the neuromuscolar control: the trunk is more than middle of the bodyweight and an uncontrolled centre of mass movement create consequence on the distal districts as hip and the knee: the dynamic valgum is offen associated with a weak control in the hip abduction, the hip's external rotation and the trunk lateral flexion. (Hickey Lucas, Kline, Ireland, & Noehren, 2017).

Figure 5. The acyclic sport tecnicque requires “dangerous” situation for the knee in order to achieve a better performance from https://dailytitan.com/2018/10/cal-state-fullerton-volleyball-long-beach-state/

The acyclic sport performance usually develops with a continuos and violent sidestepping and a repeated landing jump cycle, these movements are usually researched by the athlete. Basing on the knee anatomy and on the bimechanical knowledge everyone of these patterns cause an antero-posterior tybial shift which is limited thanks to the ligament action, making the sport practice one of the risk factor for the anterior cruciate ligament health (Jackson, Beach, & Andrews, 2017; Palareti et al., 2016).

The tybial shift results offen associated with an uncontrolled and sometimes functional, as shown in figure 5, movement of other body districts: athletes usually perform sidestepping and jump-landing without controlling the trunk in order to be more performant, this fault of coordination, especially in the concentrical phase can induce a valgum knee (Foley, Bulbrook, Button, & Holmes, 2017), furthermore this condition is increased by an excessive proximal movement: flexion and adduction associated with hip lateral swing and arm’s wawe increase the valgum value peak moment (Donnelly, Lloyd, Elliott, & Reinbolt, 2012).

The imbalance is common to every reported conditions, in this case it is, at main, an uncorrect coordinative strategy that induce an excessive abduction and an high valgum peak moment on the knee, as reported by Myer et al.: the inability to control the torque by the athlete’s muscle during the sport maneuvres, especially in the ligamentous dominance conditon, generates an unsufficient strenght and a weak control develompment; this unsuccesfull pattern afflicts the female population since the puberal age and it induces an high valgum motion and abnormal forces on the passive structures.(Myer et al., 2011) .

Furthermore, the imbalance act not only on the frontal plane, as in the dynamic valgum knee case, but also it induces an effective stress on the sagital stabilization plane: a lower flexory grade is directly related with a knee's injury, this fact is typical of female and it is due to the different landing approach between male and female; as reported by Howell, woman usually impact the ground with a more extended knee in comparison with male athletes, the positive relation between the uncorrect landing task on the sagittal plane and knee injury is proved also by a less angle of flexion reached by injuried female athletes in comparison with healthy athletes (Howell, 2013), the uncorrect landing and injury shows a positive relation: analysing the jump and landingof 829 young american male and female soccer players , the subject that perform an uncontrolled and no coordinate landing during the trial shows an higher relation with the anterior cruciate ligament rupture (Padua et al., 2015).

On the basis of the reported researches the woman population since the menarcal age (Froehle, Grannis, Sherwood, & Duren, 2017) shows high static and dynamic predisposing factors on being afflict by anterior cruciate ligament rupture: a correct neuromuscolar control during a specific task could be the main prevention strategy in order to reduce the risk factor induced by the anatomical and biomechanical disadvanteges.

2.2 Quality of Movement

2.2.1 Integrated Systems of Movement

The previous researches (Froehle et al. 2017; Hickey Lucas et al. 2017; Howell 2013; Myer et al. 2011; Padua et al. 2015) enhounced that the dynamic valgum knee is caused not only by anatomical but above all by an uncorrect coordinative pattern, the main line guide proposed a relevant treatment for the dynamic valgum knee is at main a local muscular reinforcement and a improve in coordination skill, is this an efficient and sufficient strategy in order to achieve a correct movement? Gray Cook, one of the most important movement coach, theorized the movement as the result of several aspects (Cook, Burton, & Hoogenboom, 2014a) this theory is the base of the trainer's philosopy:"training the function and the experience instead of training the muscle".

This phylosophy of training is available thanks to a global approach to the movement: as Cook has said for years the training sacrifices the global in the name of the analyitcal approach. This is opposite in comparison with the human movement's development; on the basis of his studies Cook have enhounced the regional interdipendence, this theory explain that human function and disfunction is a sum of several segment interaction and every part can influence the other: the correct pattern, composed by an accurate equilibrium between the proximal stabylizator and dystal effector, is common in child and it is the best pathway to fix a "functionally correct schema". Because of the sport practice and more in general of the life it happens a dystalization of the motor control (Cook et al., 2014a; Cook, Burton, & Hoogenboom, 2014b), that can induce an uncorrect pattern in order to fast learn a good sport technique.

As reported the movement and the stabilty are the result of several interaction between different antrophometrical areas and different body systems, this concept is easy feasible for the knee; thanks to this intermediate position, this articulation is perturbated from: distally the foot movement and stability, and proximally the hip movement (Kapandji,2011).

Analyising the literature about the knee's biomechanil, the regional interdependence and the dystalization can be possible explanations for the dynamic valgum knee, however the literature usually reports 3 main strategies of recovey: the local renforcement, the specific neuromuscolar training and the core stability.

These strategies are usually performed in a separate way, anyway since a couple of years the movement is not only theorized as the sum of several aspect but, it is the result of the interaction of different aspects: the central neuromuscular control,the mechanical adaptation of the tissue andthe muscolar synergy.

A "bad" movement offen seems to be a predictor of the injury , anyway a recent video analysis has revealed that the no contact injury situation and no injury situation show a common foot position without relevant difference highlighting the inside load, as probable main cause,inspite of the apparent movement ,(Koga, Nakamae, Shima, Bahr, & Krosshaug, 2018).Although the injury sample reported by them presented only 10 video analysis, their conclusion may lead to analyze more significantly the movements chronic adaptions considering not only the neuromuscolar adaptations but also the other aspects that the human body presents by focusing on the internal tissue resistance.

2.3 **The Deepest Level**

2.3.1 **The Connective Tissue**

In order to a deeper knowledge about the human body, since a couple of years some different approaches have been considered; a part of the movement science is trying to define different features about the human tissues, theorizing new definition as in the case of the muscle. The old definition qualifies the muscle only as a dynamic mover and a statical balancer influenced only by the neural control.

The new approach, known as holistic, at main found its theory on the viscoelastic tissue named as fascia, the last definition about is tissue has been elaborated in the 2017 (Adstrum, Hedley, Schleip, Stecco, & Yucesoy, 2017)and lead to a new muscle definition: the muscle modulate the tension in synergy with the bone and the connective making tissue the body movements the consequence of several interactions between differents systems.

The fascia is defined as the tissue that at most communicate with every structure present in the human body, the viscoelasitc characteristic is due to the connective tissue that at main compose it. For years the scientific research has been organized cell and extracellular matrix, as the content and the container. The connettive tissue is the main of the container's composition and there is a special cell population, the fibroblast, providing the specific composition through extra cellular and intra cellular process. This tissue, also known as extracellular matrix, presents plastic and mechanic charactristic and it is composed mainly by the collagen. This protein is usually described as a triple-helix protein stabylized by different bond.The structure presents not only bidirectional affinity but also confers tensile strenght and tension resistence on the tissue (Ricard-Blum, 2011). A depth analysis of the connective tissue has point out its complexity which has induced the scientific community to change the containg and container theory and to consider the sensorial pathway between cell and extracellular matrix, now considered a full of process environnment.(Piancino et al., 2017) The holistic approach, proposed by several researchers, based their line guide on the connective tissue and especially it describes in the human body several chains composed by connective and muscle, also known as myofascial chains The theory by Thomas Myers (2014**)** describes 9 differents myofascial chains in the human body named Myofascial Trains. Each line is the sequence of different "stations", but the line is not only a topographic organisation but every part of the line presents a specific tensegrity which influence the displacement of that line.

2.3.2 **The Spread of Tension: The Myofascial Trains**

The economy and the efficiency of a determined motor schema is the main objective conditioning every structural adaptations in the human body (Piancino et al., 2017; Jan Wilke, Schleip, Yucesoy, & Banzer, 2017).

The tensegrity is a property present in the human body cell's (Obiettivi et al., 1993). the scientific research try to extend the tensegrity concept to the human body and how the mechanical load can modify the shape and the funcion of the human body.

The connective tissue assure a physical link between every tissue in the human body,with some modern authors reporting that the link is not only a contact but also the transmission of mechanical stimuli that induce tension in the human body (Findley, Chaudhry, & Dhar, 2015; Maas & Sandercock, 2010). Anyway it has also demonstrated as the connective rigidity act not only on the tension's modulation in the adiacent structure but also act as an important limitation factor on the movement (Jan Wilke et al., 2017),

Figure 6. A sport gesture is a multisegmental event that involves all the body; the fascial system is the one which spreads the tension following some myofascial chains. .from https://www.foxsports.it/2018/11/08/cinque-gol-piu-belli-cristiano-ronaldo-champions-league/

Analyising the figure 6, a common gesture in a sport as the ball kick is a multisegmental event, the movement produces , the segment displacement, but also it induces a stress to the fascial system,.This tension is present in every part of the body, and it appears clear the sinergic action between the internal tension and the motor control (Findley et al., 2015). Basing on the their line guide on the connective tissue and especially define the human body composed by several myofascial chains; the myofascial trains theory by Thomas Myers joins the muscles to the connective tissue confering in it several properties.

The tension trasmission is accredited by several cadaveric and animal studies that confirm the Myer's Myofascial Trains theory(J. Wilke, Vogt, Niederer, & Banzer, 2017; Jan Wilke, Niederer, Vogt, & Banzer, 2016; Jan Wilke et al., 2017) , some researchers want to point out if the connective connection modify only the passive structure or it is possible to deduce a vivo effect. According with the Myofascial Trainstheory, some researchers reported as a specifical neck stretching and a myofascial chain protocol induce the same effect on the ROM imporovement of the cervical column (Jan Wilke, Niederer, et al., 2016)at most increasing the lateral flexion(J. Wilke et al., 2017). Furthermore this results, according with otheliterature, show the Myer's Myofascial theory is sceintificaly evident for 3 different lines (Jan Wilke, Krause, et al., 2016): the superficial back line, the functional back line and the frontal back line.

These reported studies follow the holistic phylosophy and give to the human body a global approach in order to understand the disfunction that afflicts the movement pattern; as recently theorized the movement need new model, mixed by biomechanical and anatomical notions, in order to better understand the human plasticity in the motor schema elaboration.(Dischiavi, Wright, Hegedus, & Bleakley, 2018).

In light of the previous literature about the connective tissue's properties, especially its mechanotrasduction and mechanotensegrity, the statement "the structure influences the function and the function conditions the structure" shows a consistent realibility. The motor pattern is at the same time a perceptible result and a depth modifier of the human structure. The movement is , generally, a two joints' displacement, and its amplitude, known as ROM, is a feature of an healty joint.

Although it is universally accepted that the ROM is the consequence of connectival features, it miss a uniquiness about which real acts on it.One of the pillars, presented by the integrated and global theories, is the active link between global and analytical (Dischiavi et al., 2018; Findley et al., 2015; J. Wilke et al., 2017; Jan Wilke, Niederer, et al., 2016) . The repetition of specific range of movement, as during the sport training, induces adaptations on the human body’s structure and function; in light of the previous literature it would be necessary to understand if a relation exist between structure and function.

CHAPTER 3

METHODS

3.1 Sample

According to the most recent literature research, the chosen sample present several risk factor: volleyball practice (Myer et al. 2011)female population (Beynnon et al., 2014; Hewett, 2017; Stanley et al., 2016) belonging to different developing categories team aged between 13- 19 years (Hewett 2017; Mall et al. 2014; Myer et al. 2011).. If a subject suffered a previous knee injury or has played volleyball for less than one year were excluded. The volleyball category are defined following the portuguese volleyball federation rules. All the athlete have signed the permission according to the Oviedo Conference (appendix A) .

3.2**Tests**

The previous sections reported somissues about movement and especially they explained a link function structure, in order to apply this theories to the purposes of this research it was necessary a depth research of suitable test. The next section presents the selected tests and the reference's support.

3.2.1 **Quality Of Movement Tests**

According to the reported literature this thesis analyzed the relation between structure and function.

The two test were: sit and reach and the FMS score

3.2.1.1 **Sit and reach**

Refering to the global theories (Dischiavi et al., 2018; Jan Wilke, Krause, et al., 2016), it has been presented the myofascial trains that shows that in the humanthere are several lines that link distant part; one of these is the back one which links the body from the head to the feet through the posterior myofascial tissues, as hip and back muscles. A recent meta analysis has shown that the sit and reach test is the most efficient in order to analyze the hamstrings flexibility (Mayorga-Vega, Merino-Marban, & Viciana, 2014). The scientific research elected the hamstrings' flexibility-estenxibility as one of the most important parameter for the whole body's flexibility (Miyamoto, Hirata, Kimura, & Miyamoto-Mikami, 2018), furthermore an electromyographical analysis confirm that the sit and reach test involves the back muscles, especially the erector spinae (Mookerjee & J.McMahon, 2014). All of these muscles belong to the superficial back line theorized by Thomas

Myers so it suggests that the sit and reach test is an usefull tool in order to evaluate the pre-stress on the the back line and to provide infornation about the general flexibility.

3.2.1.2 FMS score

To evaluate the global mobility of a subject and the control of the movement, Gray Cook has developed 7 differents movement which compose the FMS protocol (Cook et al., 2014b, 2014a). This procedure is commonly used to evaluate the adult athletes, and it is usually retained a high risk injury a score ≤ 14. The score informations provided by the FMS are not the only, some authors have retained useful in the injury prevention possible asymetries between the two sided of the 5 monolateral tests (Liebenson C., May 2017). Although the FMS test is not retained an injury predictor for the injury risk during the adolescence (Bardenett et al., 2015). Some scientific researches have reported that low score in FMS is associated with biomechanical disfunction (Abraham, Sannasi, & Nair, 2015; Bardenett et al., 2015; Martin, Olivier, & Benjamin, 2016), making the FMS protocol an usefull tool to prevent injury as from the young categories.

Figure 7. The FMS protocol is a 7 movements (5 left and right, 2 bilateral) protocol. Adapted by (Cook, 2010a)

3.2.2 **Biomechanical Analysis**

3.2.2.1 **The Dynamic Valgum Index**

Since the 80' the Orthopaedic Association has chosen the frontal projection of the quadriceps femoris angle, known as q angle, as the knee's injury predictor (Almeida et al., 2016; Herman et al., 2008; Herrington et al., 1989; Horton & Hall, 1989). Recently a meta analyisis found that the dynamic valgum knee is in relation with the hip dynamic (Dix, Marsh, Dingenen, & Malliaras, 2018). According with this fact some researchers instead of using only the q angle's frontal projection, have theorized a more accurate evaluation method: "Dynamic Valgum Index".

This Index, theorized by Scholtes and Salsich (2017), consider two lines in the lower limb (Figure 9): (i)the line one made of two segments, the first segment from the hip to the knee and the second from the knee to the ankle crosses the leg from the hip to the ankle (proximal-distal evolution), reports the frontal projection of the q angle; and (ii) the second line links the hip to the controlateral hip (lateral evolution), this lateral line is an usefull tool to analyze the hip's movement.

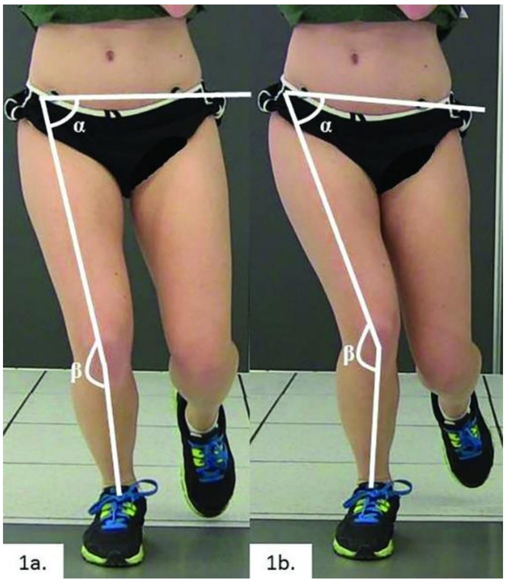

Figure 8. The valgum knee index describes two lines i) hip-knee-foot and ii) hip-hip;. Adapted by(Scholtes & Salsich, 2017)

3.2.2.2 **Single leg squat**

The “Dynamic Valgum Index” provides more complete information about the dynamic valgum knee. It analyzes at the same time the movements (2 hips, 2 knee) that are universally recognised as inducer of the dynamic valgus knee.

There are several movements, as step down, drop jump and single leg squat which has been commonly used to observe the dynamic valgum knee. Although it is believed that the coordinative skill could influence the test performance, several researchers have reported that the single leg squat is probably the more usefull tool to evaluate this abnormal attitude without any difference for novice and experts performers (Tate and True, 2015; Ugalde et al., 2015).

3.2.2.3 **The Landing test**

An uncorrect landing could cause a traumatic event as the anterior cruciate rupture, as reported in this thesis several unbalanced landing can stress the ligament increasing a rupture’s risk (Howell, 2013; Padua et al., 2015; Waldén et al., 2015). In the last five years, some researches , enhounced that the landing test unrolls an important preventive function on the anterior cruciate rupture (Jones, Herrington, Munro, & Graham-Smith, 2014; Mehl et al., 2018), this concept has been developed and two researches reported the importance of the force acting on the knee using a force platform (de Tillesse et al., 2018; Dix et al., 2018) to analyse the force acting on a knee during the single leg landing.. Anyway the single leg landing is not a specific technique of the volleyball. An exhaustive analysis made by some researchers in 2010 (Lobietti et al., 2010;) reported 831 landings, the 74,7% happened with a two feet patterns . The two feet landing pattern was a typical of high-ball spike landing 79% and 84% and of middle attack landing 83%. In the last 10 years several physical trainer have taken a line that research the maximum specificity both for the performance and for the injury prevention (C. Liebenson, 2017)In order to get the most accurate and specifical information the maximal force on the x, y and z axes were recorded after the volleyball landing(Tilp & Rindler, 2013; Zahradnik, Jandacka, Uchytil, Farana, & Hamill, 2014).

3.3Procedure

The tests took place in 3 different days (between the first day and the last day we had 30 days) : i) the first day were collected the data about the antropometrical and general information, all the subjects perfomed the landing test and the sit and reach, ii) the second day the subjected performed the FMS and iii) thet last day the single leg squat.

3.3.1 First day

3.3.1.1 Antropometrical and general information

The sample completed the questionnaire about his carrer (years, years of practice, hour of practise per week) and the leg dominance (right or left). The tape-metro model Stanley 5 meter was used to register the height (cm); a balance scale 100 by kalendji was used to record the weight (kg); the body max index was calculated considering the previous two variables and expressed in kg/m2. The subject was in case of previous injury to the knee or less than 2 years of volleyball practice.

3.3.1.2Warm up.

The force platform warm up (objective neuromuscolar activation 15” work, 30” recover) was composed of 15” speed ladder low skip, 15” squat isometric at the maximal angle (go lowest you can and stay), 3 series of 3 repetition of squat and 3 series of 2 single leg squats each leg, 3 run up of attacks, before the test the subject analysed the run up area in order to get spatial information.

3.3.1.3Landing test

After the warm up described in 3.3.1.2 every subject performed the run-attack, in order to prevent any vibration interfence the kistler platform was located in the basement of the sport palace of Lousa; in order to avoid any localization-landing problem the kistler platform was under a thick carpet, the area of the test is limited by another carpet which defines a line long 308 cm, anyway every athlete was free to chose the start point of the run in order to create more a real-training situation. The platform timer started after a vocal signal and it recorded 8 seconds, during every subject had to perform the jump.The attempt was unvalidated if the athlete performed a wrong run technique, the athlete landed out of the platform and in case of fall after the landing. In order to get a consistent run, the vocal feedback during the run was: think you have to score the final point of difficult game”. The first valid attempt was recorded and its data were transmitted to a computer located in the control position controlled by a supervisor.

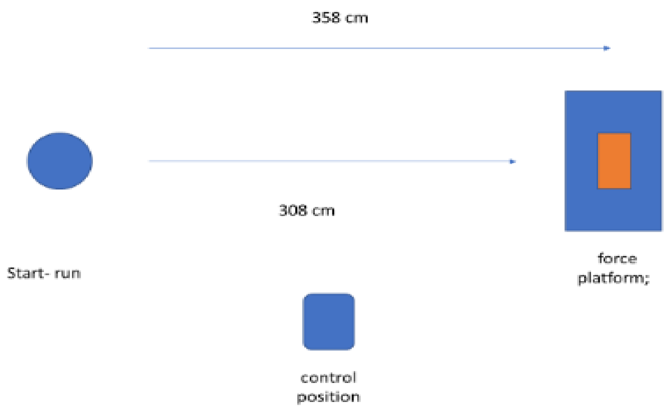

Figure9. Description of the landing test: position of the tools and of the supervisor.

3.3.1.4 Sit and reach

The subject performed the sit and reach after the force landing test. The sit and reach was performed using a sit and reach box. This special box was equiped with a measuring stick that allow to measure the flexibility of the subject. Each subject seat with the feet touching the box and the extended leg. After a supervisor's check he flexed the body in direction of the thighs maintaining extended the arms. It was measured the distance between the third finger of the hand and the body. Three attempts were performed and the best result was recorded.

3.3.2 Second day

3.3.2.1 Warm up

The FMS warm up (objective neuromuscolar activaction, 15"work : 30" rest) was composed of 15" speed ladder, 15" squat isometric at the maximal angle (go lowest you can and stay), and 3 series of 3 repetition of squat.

3.3.2.2FMS

The FMS test were performed following the reported protocol (Cook, 2010a) (5 movements reaching, rotary stability, lunging, stepping and leg raising have left/ right; 2 movements squat and push up no) : the squat, the lunging were performed by using a plastic bar 145 cm long; the same bar was used to the leg raising for an easier relevance; the stepping consisted by overpass a 70 cm high ostacle; for the reaching a bar 50 cm long is used, every cm of the bar was marked, the surpevisor record the movement.

3.3.3 Third day

3.3.3.1 Warm up

The single leg squat warm up (objective neuromuscolar activaction, 15” work: 30” rest) was was made of 15” speed ladder low skip, 15” squat isometric at the maximal angle (go lowest you can and stay), 3 series of 3 repetition of squat and 3 series of 2 single leg squats each leg.

3.3.3.2 Single leg squat:

Before performing the single leg squat, every subject was marked to define the dynamic valgum index with two lines, the line one linked the ankle and antero superior iliac spine passing thorugh the second line was from one side antero-superior iliac spine to the other side . The range of the analysis began three frames before the descedent phase the single leg squat was invalidated if the subject fell on the floor.

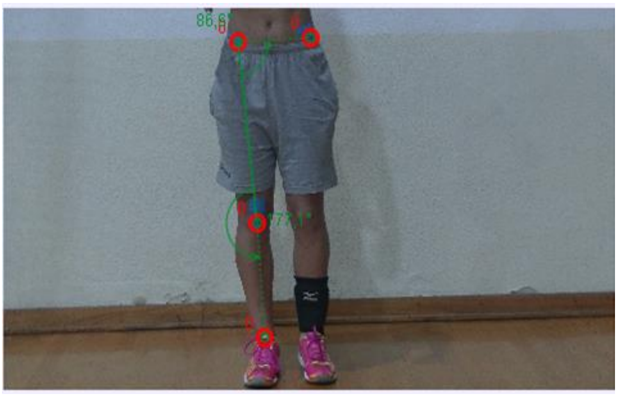

Figure10. Starting position of the single leg squat.

The lowest hip’s angle adduction and knee’s frontal plane angle were recorded; and the single leg squat end when the subject re balanced picture.

Figure 11. The peak of the angle and the recovery position

The tools were located as described in the figure 12

Figure 12. Tool's position during the single leg squat.

3.4 Variables

The variables analyzed were 48 : 1) 7 antrompometric; 2) 14 defined quality of movement 3) 27 biomechanical (appendix b).

3.4.1 Antropometric and general informations

The sample completed the questionnaire about his carrer (years, years of practice, hour of practise per week) the leg dominance (right or left). the antropometric and general informations provided 7 variables

3.4.2 Quality of movement

FMS

The FMS was recorded by using a 0-21 scale, this score is the sum of 7 different single test which were classified by a 0-3 scale. . The total score was the result of the sum minimum value of the monolateral test and the bilateral test score.

The FMS provided 8 variables to the main matrix, furthermore the FMS provided other informations for other matrixes i)5 in the symmetry table, ii) 5 in the total score matrix and iii) 1 in the lower than 14 table.

Sit and reach

The sit and reach provided one variable.

3.4.3 **Biomechanical analysis**

This analysis considered two parts: i) the video analysis of the single leg squat; and ii) the force landing's analysis .

Anyway according to the reported literature (Jones et al., 2014; Mehl et al., 2018; Scholtes & Salsich, 2017), it could be defined 5 variables that are risk for the knee : 1) scholtes and salsich index knee; 2) scholtes and salsich index hip; 3) maximal force x; 4) maximal force y; 5) maximal force z.).

Single squat video analysis

The video analysis was composed by two differents parts: i) an angular, and ii) a time analysis. Both analysis was performed using the software Tracker 3. The start postion, both for the knee and hip, was recorded and considered three frames before the descedent phase. the angle peak both for the knee and for the hip, is the lowest angle performed during the entire test; the variable amplitude both for the knee and for the hip, is the difference between these two variables; the Scholtes and Salsich index is derived by 90°- peak of angle adduction for the hip, wheras for the knee is 180°- peak dynamic valgum angle, the number of variable of the angle analysis was 8.

The Time analysis was composed by several categories: the first one anlyzed each phase's lenght: the time starts three frames before the descendent phases, the end is when the subject recover the start position; the second part evidenced each peak's time, the last category wanted to point out if the angle's peak happen during the eccentric or the concentric phase, in order to do this a 1-2 scale is made: 1 = peak during the eccentric phase, 2 = peak during the concentric phase, the number of variable of the angle analysis was 7 .

Landing's analysis force platform:

The ground's forces at the landing moment have been recorded by using the force platform Kistler 3.0, this platform, which is recognised as gold standard in force analysis (Peterson Silveira et al., 2017) provided the gorund forces at landing on the axes x, y and z (newton), for a total of 9 variables; this force analysis is accompained by a time analysis (seconds), which record the first contact on the platform and the last one, the difference between these 2 times provides the time of contact, for a total of 3 variables.

3.5 **Statistical treatment**

The mean, the standard deviation were calculated. the correlation matrixes,using the Bravais Pearson correlation coeficient, were calcutated for a $p \leq 0.05$, in order to define possible relations between the different variables. All the statical treatment was made using Microsft Excel Software.

The main correlation matrix analyzed all 48 varables. Other matrixess: i) the relation between the variables age and age of practice and the variables about the quality of movement ii) the relation between the phase of the peak of the angles (hip and knee) recorded during the video analysis and the biomecanic and quality of movement variables iii) the relation between the score simmetry of the two sided F.M. S. score, the biomecanic variables (video analysis and force platform) and the quality of movement variables iv) the relation between the 5 variables, which are the sum of the single score of each side FMS, and 3 variables: the 2 about the Knee and Hip Scholtes and Salsich Index and the sit and reach score; v) The lastmatrix related the FMS lower than 14 to the 5 variables retained risk factor.

CHAPTER 4
RESULTS

4.1. **Sample.**

The sample was composed of 23 young female athletes (Table 1) aged 14.35 . ±1. 53 years, the athletes belong to developing categories: 11 playing in the “infatis” team, 8 playing in the “cadetes” team, 4 playing in the “juvenis”. Twenty right handed and 3 left handed; no one afflicted by a previous knee injury. The athletes practice volleyball for 4.91 ± 2.04 years, practicing Volleyball 5.57 ± 0.84 hours a week.

Table 1. Antropometry and carreer's characteristics of the sample.

	AGE (years)	VOLLEYBALL PRACTICE (years)	WEEKLY VOLLEYBALL PRACTICE (hours)	WEIGHT (kg)	HEIGHT (cm)	BODY MAX INDEX (kg/m2)
Mean s.d.	14.35 ±1.53	4.91 ±2.04	5.57 ± 0.84	55.22 ± 6.04	163.38 ± 6.33	20.65 ± 1.46

4.2 **Quality of movement**

4.2.1 **Functional Movement Screen**

Each athlete performed the “Functional Movement Screen” by Gray Cook (Cook, 2010a), the test was composed of 7 movements: 5 one sided and 2 bilateral, the evaluation scale is from 0-3 according to the Gray Cook’s evaluation criteria (Cook, 2010a); the sum among the 2 bilateral scores and the minimum between left and right movement produced a score between 0 and 21. The table 2 shows each movement’s result.

Table 2. Results of the FMS test

	REACHING Points		ACTIVE LEG RAISING Points		ROTARY STABILITY Points		LUNGING Points		HURDLE STEP Points		SQUAT Points	TRUNK STABILITY PUSH UP Points	TOTAL SCORE Points
	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT			
Mean s.d.	2.61 ± 0.58	2.78 ±0.42	2.35 ± 0.65	2.43 ±0.66	2.35 ± 0.49	2.17 ±0.58	2.22 ± 0.52	2.26 ±0.54	2.30 ± 0.63	2.22 ±0.66	1.96 ± 0.64	1.61 ± 0.66	15.17 ± 2.39

The total score average was of 15.17 +. 2.39; as shown in figure 2 each team showed differents score the infatis performed 14.36. ±2.42 points wheras the cadetes 15.88 ±2.23 points and the juvenis 16.00 ±2.45 points.

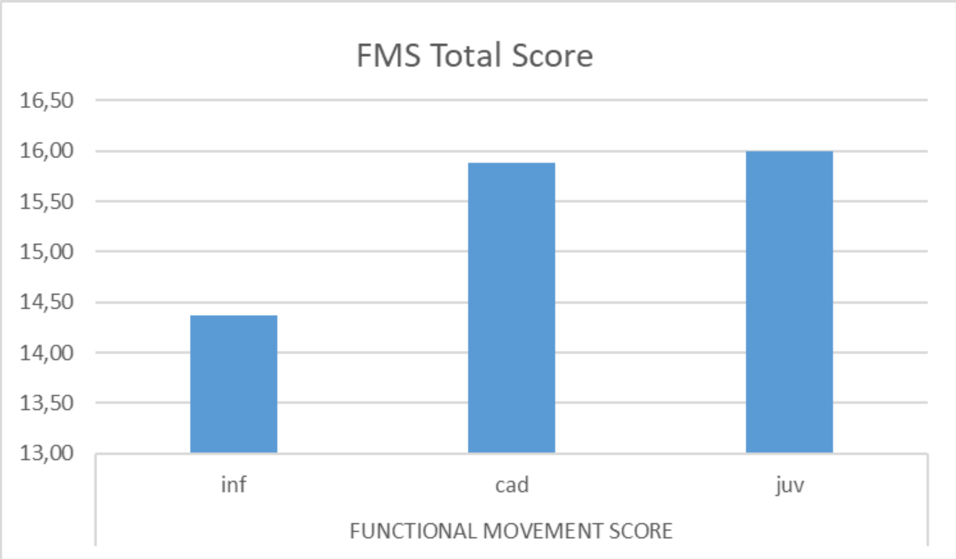

Figure 13. FMS (points). Team results.

4.2.2 Sit and reach.

The subjects performed the "Sit and Reach Test" according to the protocol (3.3.1.3) scoring a mean of 27.48 cm ±5.58 cm.The infatis and the juvenis team scored 25.09 cm ± 5.58 cm and 26.25 cm ± 2.99 cm wheras the cadetes performed 31.38 cm ± 4.75 cm

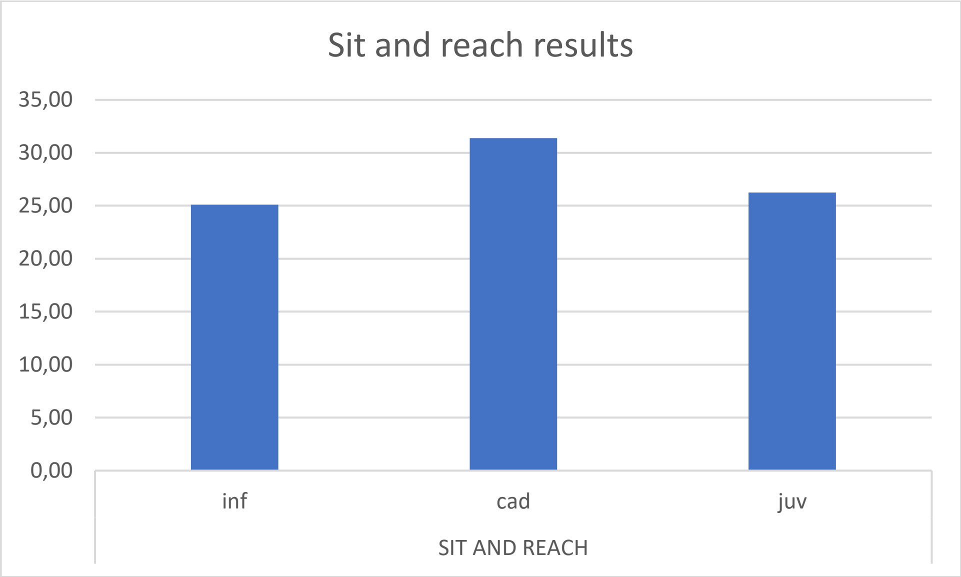

Figure 14. Sit and reach (cm). Team results

4.3**Biomechanical Anlysis**

4.3.1 **Single Leg Squat**

The single leg squat is composed of two differents parts: angle analysis, focus on the knee and the hip movements; time analysis: focus on the 2 phases: the concentric and the eccentric.

4.3.1.1 **Angle Analysis:**

The q angle's start position mean was 175.15° ± 2.76°, the mean at the peak of the dynamic valgum moment was 165.33° ± 7.29° The Scholtes and Salsich Valgum index for the knee was 14.67°± 7.29°, while the hip's angle at the start position was 84.44°± 2.54°, at the displacement peak the angle showed a 75.53° ±5.00°, the Scholtes and Salsich index was 14.47°± 5.00°. The angular amplitude mean was 9.83°± 7.41° for the knee wheras it was 8,91°, ± 4.92° for the hip.

Table 3. The single leg squat angle analyisis: q angle ,the angle of the hip adduction and the Scholtes and Salsich valgum knee index.

ANGLE ANALYSIS									
	Q ANGLE (°)			HIP ANGLE ADDUCTION (°)			SCHOLTES AND SALSICH VALGUM INDEX (°)	
	START	PEAK DYNAMIC VALGUM MOMENT	ANGLE AMPLITUDE	START	ADDUCTION PEAK	ANGLE AMPLITUDE	KNEE	HIP
Mean	175.15	165.33	9.83	84.44	75.53	8.91	14.67	14.47
s.d.	± 2.76	± 7.29	± 7.41	± 2.54	± 5.00	± 4.92	± 7.29	± 5.00

By analysing the video the 23 athletes were classified: the 48% (11 athletes) performed a controlled squat, the 18 % (4 athletes) showed a Scholtes and Salsich dynamic valgum knee index greater than 15°, the 17% (4 athletes) performed the test showing a Scholtes and Salsich hip index greater than 15°, and the remaining 17% (4 athletes) showed both uncontrolled patterns during the test performance (figure 3).

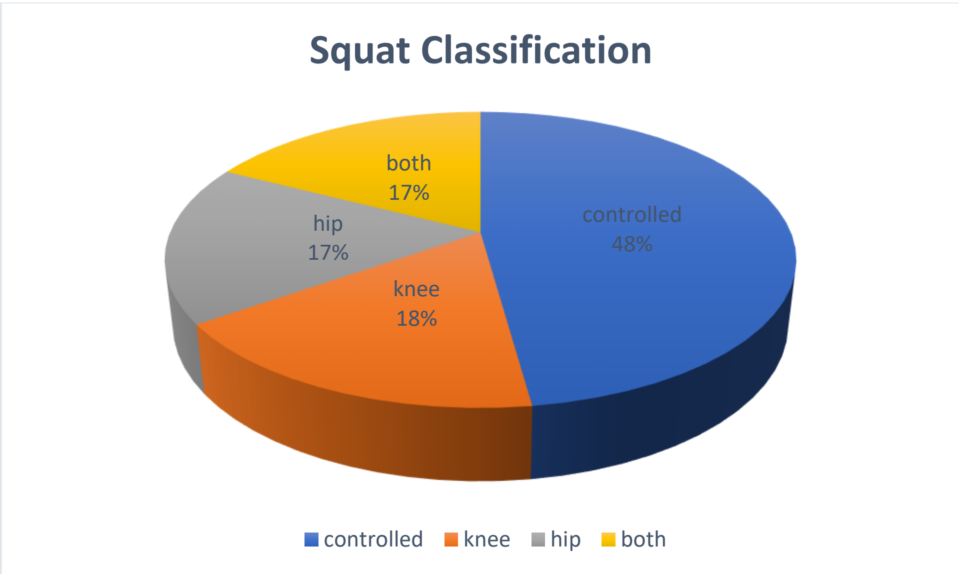

Figure 5. Sample's squat classification

However by analysing each team mean, the cadetes team showed a dynamic valgum knee index and a hip's maximal index 11.45° ±3.45° for the knee, 13.41° ±4.05° for the hip. The teams, infatis and juvenis, showed a mean in the dynamic valgum knee index 18.65°± 11.23° (juvenis) and in the hip displacement 16.08° ±6.72°, the infatis team presents a 15.57° ±7.42° dynamic valgum index and a 14.66° ±5.29°.

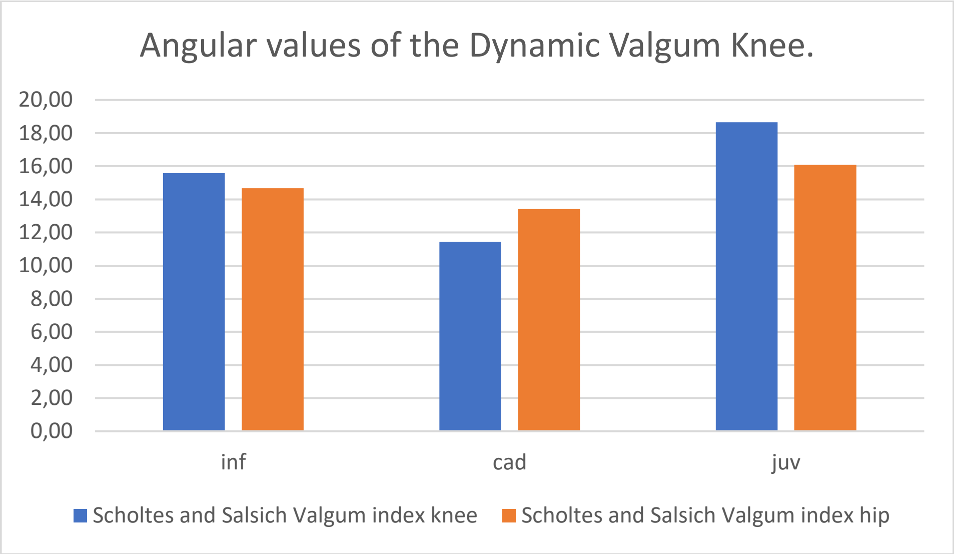

Figure 6. Dynamic Valgum Index for the knee and the hip. Team results

4.3.1.2 **Single Leg Squat Time Analysis**

The single leg squat is composed by two phases: an eccentric one and a concentric one; the eccentric phase has taken1.30 s ±. 0.28 s while the concentric has taken 1.18 s±. 0.27 s. Each squat has taken 2.48 ±0.41 s; the time of the dynamic valgum knee peak was 1.33 s ±. 0.41 s while the hip's angle peak was 1.32 s ± 0.36 s.

Table 4. Time analysis of the single leg squat: phases, totatl time, time of the angle peak and phases of the angle peak

TIME ANALYSIS (s)							
	PHASES		TOTAL TIME	ANGLE PEAK		PHASES ANGLE PEAK	
	ECCENTRIC	CONCENTRIC		KNEE	HIP	KNEE	HIP
Mean s.d.(s.)	1.30 ± 0.28	1.18 ± 0.27	2,48 ± 0.41	1.33 ± 0.41	1.32 ± 0.36	13 e. ph 10 c. ph	12 e. ph 11 c. ph

As described in the figure 6 the cadetes showed a total time of 2.77 s ±0.38 s. The eccentric phase took 1.43 s ±0.27 s, while the concentric 1.34 ±0.34 s.d.; The infatis showed a total time of 2.29 s ±0.4 s, and the eccentric of 1.22 s ±0.32 s and the concentric of 1.06 s. ±0.22 s. The juvenis showed a total time of 2.43 s±. 0.09, an eccentric phase of 1.25 s ±0.05 s and a concentric phase of 1.18 s.±. 0.10.

The angle's peak took place 13 times during the eccentric phases and 10 during the concentric for the knee; whereas it happened 12 times during the eccentric and 11 times during the concentric for the hip. (figure 7 and figure 8).

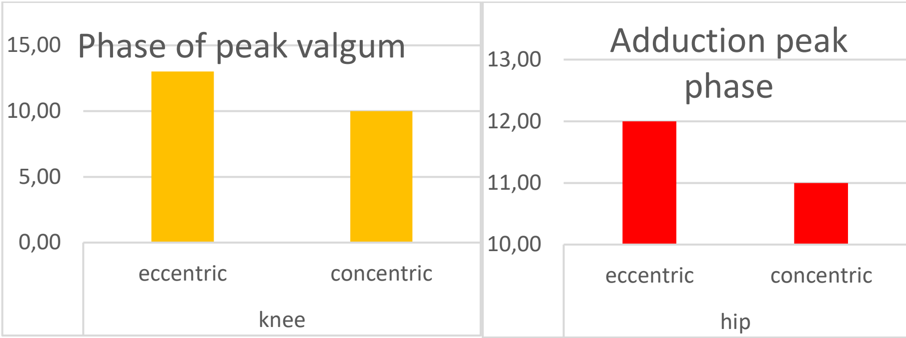

Figure17. Peak angle analysis of the phases (hip and knee). .

4.3.2 **Force Platform**

As the "Single Leg Squat" the force platform analysis is composed of a kinematic analysis and a time anlysis; the kinematic analysis detected the force displacement in x, y and z wheras the time analysis recorded the start and the end of the landing.

4.3.2.1. **Force Analysis**

The highest force happened on the axis z 3212.08 N.m ±1040.87 N.m, wheras the lowest was on the axis y 123.78 N ±61.30 N, on the x axes a displacement happened 894.39 N.m±232.15 N.m; as described in the table 6, this trend was confirmed by both, the minimal moment z 27.79N.m ±. 60.81N.m, y -167.23 N.m ±95.18 N.mand x -85.68 N.m ±74.02 N.mand the moment difference z 3184.29 N.m±1014.32 N.m, y 291.01 N.m±118.47 N.m, x 980.06N.m ± 276.77 N.m.

Table 5. The ground reaction force on the x, y, z axes during the volleyball spike landing.

	FORCE PLATFORM (N.m)								
	MAXIMAL FORCE			MINIMAL FORCE			FORCES DIFFERENCE		
	X	Y	Z	X	Y	Z	X	Y	Z
Mean S.d.	894.39 ±232.15	123.78 ± 61.30	3212.08 ± 1040.87	-85.68 ± 74.02	-167.23 ± 95.18	27.79 ± 60.18	980.06 ± 276.77	291.01 ± 118.47	3184.29 ± 1014.34

The team presented different trends. The juvenis team showed on z 3906.21N ±827.00 N , on x 1093.48 N.m±278.35 N.m and on y 118.32 N.m ± 40.98 N.m; the infatis team presented on the z axis 3173.23 N.m ±1046.28 N.m on the x axis 811.92 N.m±. 201.09 N.m and on the y axis 116.13

N.m ±54.11 N.m. The cadetes team showed on z 2918.42 N.m ±1082.48 N.m, on x 908.23 N.m ±211.79 N.m and on y 137.02 N.m ± 81.24 N.m.

4.3.2.2 **Time Analysis**

The athletes have started the contact on the force platform at 3.04 s ±0.59, the last contact was at 6.19 s ±1.49 s for a total contact time of 3.15 s ±1.29.

The juvenis team contact time was 4.17 s±. 0.98 s. The infatis and cadetes spend 2.94 s ±1.39 s and 2.92 s ±1.15 s. The infatis team started the contact at 2.95 s ±. 0.53s while the cadetes land at 3.13 s±. 0.79 and the juvenis land at 3.12 s ± 0.25s

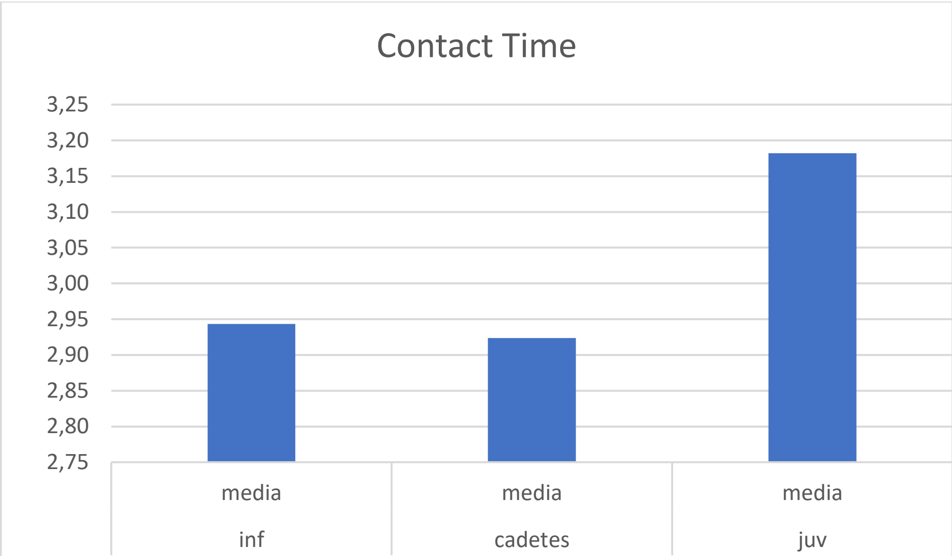

Figure 18. Duration of the landing contact time (s). Team results

4.4 Correlation study:

The variables presented in this chapter were related using the R correlation coefficient through different matrices. The main matrix show the relation between the 27 biomechanical variables (video analysis and force platform) and the all 48 variables (antropometric, quality of movement, video analysis and force platform), as reported in the table it resulted 119 correlation, 81 with $p \leq 0.05$ and 38 with $p \leq 0.01$.

The figure 7, describe how the relation are represented: the antropometric variables showed the 10% of the relations (12 relations), the quality of movement presented the 28% of the relation (33 relations) and the biomechanical presented the remaining 62% (74 relations).

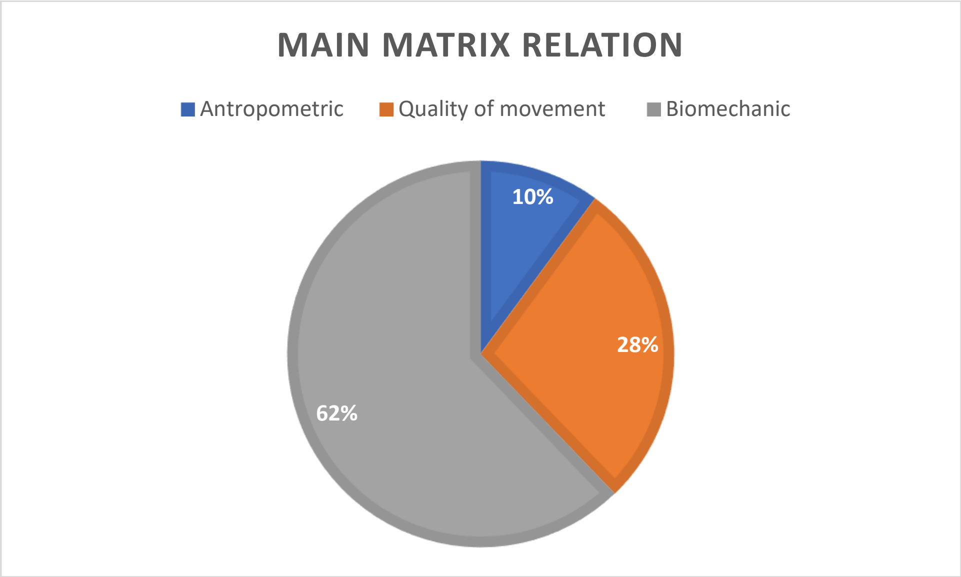

Figure 19. Percentage of the main matrix' correlation

The main matrix is integrated by other matrices: the one matrix, table 6, presented 5 variables, which are the sum of the single score of each side FMS, and 3 variables: the 2 about the knee and hip Scholtes and Salsich Index and the sit and reach score; 4 relation results, 2 with $p \leq 0.01$ and 2 with $p \leq 0.05$.

Table 6. The Correlation Coefficients of the FMS test with the Scholtes and Salsich Valgum index (knee and hip angles), and the sit and reach.

FMS TEST	SCHOLTES AND SALSICH VALGUM INDEX		SIT AND REACH SCORE
	KNEE	HIP	
TOTAL REACHING	-0.27	-0.14	-0.19
TOTAL LEG RAISING	-0.59**	-0.40	0.38
TOTAL R. STABILITY	-0.13	-0.44*	0.17
TOTAL LUNGING	0.01	-0.07	0.05
TOTAL STEPPING	-0.63**	-0.43*	-0.09

* $p \leq 0.05$.
* * $p \leq 0.01$

The other matrix investigated: i) the relation between the time variables age and age of practice and the variables about the quality of movement ii) the relation between the phase of the peak of the angles (hip and knee) recorded during the video analysis and the biomechanical and quality of movement variables iii) the relation between the score simmetry of the two sided FMS. score, the biomechanical variables (video analysis and force platform) and the quality of movement variables. All the above matrix presented no statistically significant relation. The last matrix related the FMS lower than 14 to the 5 variables retained risk factor, resulting the following relations the score $\leq$ 14 was statistically related with both angle of the Scholtes and Salsich Index for the knee (R= -0,440 $p \leq 0.05$) and for the hip (R= -0,600 $p \leq 0.01$), the relation of the score with the variables of the landing were no statistically significant.

In accordance to the reported literature this thesis explored the relation between the knee and the hip; the table 8 shows the relation among the knee and the hip angle and the FMS test that are directly about the hip movement.

Table 7. Correlation of the functional relations knee-hip. FMS and biomechanical variables.

FMS TEST	$p \leq 0.01$	$p \leq 0.05$
Stepping left	Scholtes knee angle R = - .694	Hip angle amplitude R = - .469 Axes y maximal force R = - .424
Total rotary stability		Peak angle hip's R = - .444
Total stepping	Scholtes knee angle rR= -.625	Scholtes hip angle R= - .429

CHAPTER 5

DISCUSSION

5.1 Main purposes.

This research aimed to define the relation between the biomechanical antropometric and the quality of movement variables for the female volleyball athlete with the ACL rupture (dynamic valgum knee and landing stress) risk factors.

The sit and reach test showed an R = -. 327 ($p > 0.05$) with the dynamic valgum index for the knee, which was not stastically significant. The relations were also weak among the sit and reach score and all the forces recorded by the platform during the landing.

The relation between sit and reach and the risk factors was not the only aim of the study, according to the regional interdipendece concept presented in the literature review this thesis also inteded to analyze the possibility of dysfunctions linked in far body parts. A depth analysis of the results pointed out that this hypotesis could be reliable, the dynamic valgum knee index presents a relation stastically significant with the FMS reaching test score (R= -.422 $p \leq 0.05$). This correlation links two far body parts, the knee and shoulder and it agreed with the reported literature both for the Myofascial Trains by Thomas Myers (Dischiavi et al., 2018; Krause, Wilke, Vogt, & Banzer, 2016; Jan Wilke, Krause, et al., 2016) and for the Gray Cook's theories (Cook, 2010b; Cook et al., 2014a, 2014b).

Following the regional interdipendence, the stability between knee and hip is confirmed as a key factor for the ACL rupture prevention, and it agreed with some of the main indications proposed by the sport literature which relate a better neuromuscolar control in the hip with a better knee stability (Dix et al., 2018; Ford et al., 2015; Howard et al., 2011; Jackson et al., 2017). Every test which observed directly the hip functionality (stepping and rotary stability), described in the table 8 , showed relation with the knee's (Scholtes knee angle R = - .694 $p \leq 0.01$, Scholtes knee angle R = -.625 $p \leq 0.01$) and hip's angle (Hip angle amplitude R - .469 $p \leq 0.05$, Peak angle hip's R = - .444 $p \leq 0.05$, Scholtes hip angle R= - .429 $p \leq 0.05$) and with the maximal force recorded by the force platform on the y axes (axes y maximal force R = - .424 $p \leq 0.05$).

The strenght of the relation between the knee's dynamic valgum angle and the active leg raising (2 sided score R= -.587 $p \leq 0.01$, right R= -.594 $p \leq 0.01$, left R=- .414 $p \leq 0.05$) validated more the functional link knee-hip. A relevant result is the one about what could influence the leg raising, this test could be easy defined as an active hip flexion, and among the Gray Cook's test this could be defined as the most analytical. This test is closer to a flexibility test, so it could be a possible link between this connective characteristic and the dynamic valgum knee, partly confirming the hypotesis which links connective characteristics and biomechanical pattern; however this thought would probably deserve further and more accurate research.

The variables, describing the carreer and time of training of every athletes, did not present any stastically significative relation with the studied variables. Summarizing it was confirmed the relation between the three dysfunctions (hip, knee and shoulder) that are far in the body. The relation between connective tissue and biomechanical pattern partially confirmed the Thomas Myers Myofascial Trains theory.

The main matrix of correlation (appendix b-c) proposed others relevant relations and deductions about the variables, these can be grouped in i)antropometric, ii) quality of movement, and iii) biomechanical.

5.2 Antropemtric Variables Comparison And Considerations

There was an inverse relation statistically significant between the bodyweight and the lenght of the eccentric phase during the single leg squat ($R = .429$ $p \leq 0.05$). As described in a biomechanical analysis (Choenfeld, 2010), performing a short eccentric phase during a squat stresses the knee’s ligament structure. Another antropometrical variable is related to a risk factor.: the relation between maximal force on the z axis and the height ($R = .420$ $p \leq 0.05$) confirmed the theory proposed by Thein (2017), who defined this antropometric characteristic a risk factor for the ACL rupture.

5.3 Quality of movement: FMS comparison and consideration

Although research of 2016 and 2015 (Chorba et al., 2015; Martin et al., 2016) reported that the FMS score is a poor injury predictor both of general injury and of the ACL rupture (Mehl et al., 2018), it is believed that a score $\leq$ 14 could be a "wake-up call" of risk injury since it shows poor movement pattern (Liebenson C, 2017) . The current results supported the FMS score as indicators of injury risk factor in a young sport population. This hypotesis was streghtened by two differents analyses. First, analyzing in depth the inverted relation of the FMS total score with the hip's angle (R= -.576 $p \leq 0.01$) and with the knee's angle (R= -.555 $p \leq 0.01$) showed that two risk factors of the ACL rupture were significant related to the FMS total score. The second analysis considered the relation between score lower than 14, and the same two angle. The results both for the knee (R= -0,440 $p \leq 0.05$) and for the hip (R= -0,600 $p \leq 0.01$) confered to the FMS a further relation with these two risk factors. Extending the relation to the recorded force by the platform, that this study has researched, there was no relation statistically siginifcant between both for the FMS total score and both for the lower than 14 "rule".

The FMS is a sequence of excercise which are usefull to provide information about the motor skill of a subject. Although the comparison of the sample's motor skill was not the main goals of this research, it was intersting to understand the sample's motor level. The importance of the FMS score is more and more accepted in the scientific sport community, which not only defined a relation between FMS score and young fitness but has also defined this score as indicator of the motor development (Boguszewski, Jakubowska, Adamczyk, Ochal, & Białoszewski, 2017).

In the table 8 there is a comparison between this research and some studies, which used FMS score to define the quality of movement of some young population (Abraham et al., 2015; Bardenett et al., 2015; Boguszewski et al., 2017; Chorba, Chorba, Bouillon, Overmyer, & Landis, 2010).

Abraham et al, in 2015, observed lower score in a young adolescent female and male, (15.17 current study vs 14.17 points pt Abraham et al. (2015)) this trend was confirmed in each test out of the reaching test, which presented a similar score (current study 2.57 points, Abraham et al 2015 2.59 points). The score performed by the current sample was similar to the one reported by Boguszeweski, which analyzed female hockey players. Considering the sample's age the most relevant comparison is the one with the Bardenett's 2015 study, who observed a similar age sample: high school athlete (injury and no injuried) aged between 12-18 years old. The reported score of this study were higher of the Bardenett one, highlighting how this sample showed higher quality of movement compared to a same age american one (15.17 points current study vs 13.11 points Bardenett et al 2015).

Table 8: Resuming table of the reported researches about FMS in the developing age.

		AGE	REACHING Points	ACTIVE LEG RAISING Points	ROTARY STABILITY Points	LUNGING Points	STEPPING Points	SQUAT Points	TRUNK STABUILITY PUSH UP Points	TOTAL SCORE Points
Current research	23 female volley	14.35±1.53 years old	2.57	2.22	2.13	2.13	2.09	1.96	1.61	15.17
(Abraham et al., 2015)	1005 sport practicant	10-17 years old	2.59	1.96	1.82	1.92	2.06	2.38	1.58	14.17
(Boguszewski et al., 2017) (	5 hockey players	10.6 ± 0.55 years old	3	2.6	2	2	2	2.4	1.2	15.2
	10 girls inactive	10.82 ± 0.75 years old	2.73	2.64	2	2	2	2.18	1.18	15.5
(Chorba et al., 2010)	11 girls Volley not injured	18.91 ± 1.04 years old								14.9
(Bardenett et al., 2015)(	128 sport praticant Not Injured	15.2 years old	2.67	1.98	1.56	1.97	1.91	1.86	1.20	13.11
	39 sport praticant Injured	15.2 years old	2.23	1.97	1.51	2.21	1.82	1.79	1.41	13.00

5.4 Biomechanical analysis comparison and considerations

To complete this research the analysis of the biomechanical variables has been taken in account.The biomechanical variables are of two groups, the first considered the single leg squat the second the informations (time and force) recorded by the force platform. This analysis is since it links a general pattern (single leg squat) to a specifical pattern of the volleyball (landing).

The correlation's analysis of these tests induce a question: do to higher landing force correspond to an uncorrect squat pattern? Limiting our investigation to the force and the angle, there was no relation between these two variables.

The single leg squat and the force platform presented a link between the time variables and the recorded forces. The duration of the single leg squat's eccentric presented an inverted proportionally relation with the landing force on the z axes ($R = -.495$ $p \leq 0.05$). This relation highligted as the shortness of the eccentric phase's could be a " wake up call" not only for squatting because of the stress on the knee, (Choenfeld, 2010) but also could be signal of a possible excessive stress on landing after a jump.

Controlling the duration of the eccentric phase of the single leg squat could be an usefull feedback to reduce the landing stress. Analysing in depth only the single leg squat the time analysis provided some informations about the angle of the squat, the analysis of the time of the maximal angle pointed out the following relation: The more the squat's eccentric phase is longer later the maximal angle happened, both for the hip (R= .820 $p \leq 0.01$) and for the knee (r = .779 $p \leq 0.01$).

The time analysis had also defined if the widest angle has happened in the concentric or the eccentric phase of the single leg squat; all the connections statistically significant concern the knee. A wide angle during the concentrical phase is related to the squat lenght (R= .425 $p \leq 0.05$) and to the eccentric phase's lenght (R= .424 $p \leq 0.05$). The biomechanical correlation analysis have elected the time as the parameter that can be the more usefull feedback. This information is very important because providing simple and very understable feedback could be an important way of prevention modyfing uncorrect pattern.

CHAPTER 6:
CONCLUSIONS.

6.1 Conclusions.

The main purpose was to verify the relation between the sit and reach and the risk factors of the ACL rupture, (the two angles (knee and hip) of the Dynamic Valgum Index (Scholtes & Salsich, 2017) and the maximal force of ground on x, y and z axes). The sit and reach test showed an R= -. 327 $p > 0.05$ with the Scholtes and Salsich index for the knee, which is not stastically significant.

The relations were also weak among the sit and reach score and the ground reaction forces (x, y, z). It was partially confirmed the relation between connective tissue and biomechanical pattern (leg raising right with dynamic valgum knee index R= -.594 $p \leq 0.01$; leg raising right with hip adduction angle R= -. 499 $p \leq 0.01$), confirming the Thomas Myers myofascial theory (Dischiavi et al., 2018). Several correlation (leg raising right dynamic valgum knee index R= -.594 $p \leq 0.01$; leg raising right, hip adduction angle R= -. 499 $p \leq 0.05$) confirmed the functional link hip-knee according to the reported literature (Dix et al., 2018; Jackson et al., 2017; Nakagawa & Petersen, 2018).

The relation shoulder-knee(reaching right with dynamic valgum index R= -.422 $p \leq 0.05$), could open new research in accordance to the Gray Cook's regional interdependence (Cook, 2010b) theory and to the Thomas Myers Myofascial Trains theory (Krause et al., 2016).

Although the volleyball practice presents the repetition of dangerous motor schema (landing, leg aceleration and deceleration cycles and knee side-cutting).the time spend for training volleyball and the years of carrer did not show an influence on any variables.).

The FMS score seemed to be suitable tool to detect the Dynamic Valgum Knee Index both for the knee (R= -. 555 $p \leq 0.01$) and for the hip (R= -. 576 $p \leq 0.01$)

6.2 Limitations:

The presents results must be analyzed considering some limitations: the number of subjects is relatively low 23. Since the literature does not indicate any test for the superficial back line, the choose of the sit and reach was due to the study of the muscle's anatomical insertion and is a theorical derivation. The reasearch was devoleped without cost.

6.3 Further Studies.

The deductions of this study could suggest other future researches: i) a deeper analysis of the regional interdependence between shoulder and knee. ii) analyze the phase before landing, to explore the inverted relation between the dynamic valgum index (knee angle) and the first contact on the platform, (longer pre-phase), R= -.422 $p \leq 0.05$., iii) and to find out any left-right influence in the regional interpendence.

REFERENCES.

Abraham, A., Sannasi, R., & Nair, R. (2015). Normative values for the functional movement screentm in adolescent school aged children. *International Journal of Sports Physical Therapy*, *10*(1), 29–36. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=4325285&tool=pmcentrez&rendertype=abstract

Adstrum, S., Hedley, G., Schleip, R., Stecco, C., & Yucesoy, C. A. (2017). Defining the fascial system. *Journal of Bodywork and Movement Therapies*, *21*(1), 173–177. https://doi.org/10.1016/j.jbmt.2016.11.003

Almeida, G. P. L., Silva, A. P. D. M. C. C. E., França, F. J. R., Magalhães, M. O., Burke, T. N., & Marques, A. P. (2016). Ângulo-Q Na Dor Patelofemoral: Relação Com Valgo Dinâmico De Joelho, Torque Abdutor Do Quadril, Dor E Função. *Revista Brasileira de Ortopedia*, *51*(2), 181–186. https://doi.org/10.1016/j.rbo.2015.05.003

Ayala, F., Sainz de Baranda, P., De Ste Croix, M., & Santonja, F. (2012). Reproducibility and criterion-related validity of the sit and reach test and toe touch test for estimating hamstring flexibility in recreationally active young adults. *Physical Therapy in Sport*, *13*(4), 219–226. https://doi.org/10.1016/j.ptsp.2011.11.001

Bardenett, S. M., Micca, J. J., DeNoyelles, J. T., Miller, S. D., Jenk, D. T., & Brooks, G. S. (2015). Functional Movement Screen Normative Values and Validity in High School Athletes: Can the Fms^{TM} Be Used As a Predictor of Injury? *International Journal of Sports Physical Therapy*, *10*(3), 303–308. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=4458917&tool=pmcentrez&rendertype=abstract

Beynnon, B. D., Vacek, P. M., Newell, M. K., Tourville, T. W., Smith, H. C., Shultz, S. J., … Johnson, R. J. (2014). The effects of level of competition, sport, and sex on the incidence of first-time noncontact anterior cruciate ligament injury. *American Journal of Sports Medicine*, *42*(8), 1806–1812. https://doi.org/10.1177/0363546514540862

Boguszewski, D., Jakubowska, K., Adamczyk, J. G., Ochal, A., & Białoszewski, D. (2017). Functional assessment of children practicing ice hockey through Functional Movement Screen test. *Physical Activity Review*, *5*, 105–112. https://doi.org/10.16926/par.2017.05.15

Checa, S., Rausch, M. K., Petersen, A., Kuhl, E., & Duda, G. N. (2015). The emergence of extracellular matrix mechanics and cell traction forces as important regulators of cellular self-organization. *Biomechanics and Modeling in Mechanobiology*, *14*(1), 1–13. https://doi.org/10.1007/s10237-014-0581-9

Choenfeld, (2010). Squatting Kinematics And Kinetics And Their Application To Exercise Performance S k k t a e p, *24*(12), 3497–3506.

Chorba, R. S., Chorba, D. J., Bouillon, L. E., Overmyer, C. A., & Landis, J. A. (2010). Use of a functional movement screening tool to determine injury risk in female collegiate athletes. *North American Journal of Sports Physical Therapy : NAJSPT*, *5*(2), 47–54. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/21589661%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC2953387

Chorba, R. S., Chorba, D. J., Bouillon, L. E., Overmyer, C. A., Landis, J. A., Martin, C., … Ochal, A. (2015). Normative values for the functional movement screentm in adolescent school aged children. *International Journal of Sports Physical Therapy*, *5*(3), 29–36. https://doi.org/10.1123/jsr.2016-0073

Cook, G. (2010a). Fms Scoring Criteria. *Movement: Functional Movement Systems -- Screening, Assessment, Corrective Strategies*.

Cook, G. (2010b). The 10 Movement Principles, 35–50.

Cook, G., Burton, L., Fields, K., & Kiesel, K. (1998). The functional movement screen. *Danville, VA: Athletic Testing Services, Inc*, *36*(5), 9–11. https://doi.org/10.1519/SSC.0000000000000074

Cook, G., Burton, L., & Hoogenboom, B. J. (2014a). CLINICAL COMMENTARY FUNCTIONAL MOVEMENT SCREENING : THE USE OF FUNDAMENTAL MOVEMENTS AS AN ASSESSMENT OF, *9*(4), 549–563.

Cook, G., Burton, L., & Hoogenboom, B. J. (2014b). FUNCTIONAL MOVEMENT SCREENING : THE USE OF FUNDAMENTAL MOVEMENTS AS AN ASSESSMENT OF, *9*(3), 396–409.

de Tillesse, E. A., Lima, A. A., de Oliveira, R. R., de Paula Lima, P. O., Bittencourt, N. F. N., & Almeida, G. P. L. (2018). Nonlinear association of the predictive factors for dynamic knee valgus during the forward step down test in young athletes. *Physical Therapy in Sport*, *31*(2018), e3. https://doi.org/10.1016/j.ptsp.2017.11.015

Dischiavi, S. L., Wright, A. A., Hegedus, E. J., & Bleakley, C. M. (2018). Biotensegrity and myofascial chains : A global approach to an integrated kinetic chain. *Medical Hypotheses*, *110*(November 2017), 90–96. https://doi.org/10.1016/j.mehy.2017.11.008

Dix, J., Marsh, S., Dingenen, B., & Malliaras, P. (2018a). The relationship between hip muscle strength and dynamic knee valgus in asymptomatic females: A systematic review. *Physical Therapy in Sport*. https://doi.org/10.1016/j.ptsp.2018.05.015

Donnelly, C. J., Lloyd, D. G., Elliott, B. C., & Reinbolt, J. A. (2012). Optimizing whole-body kinematics to minimize valgus knee loading during sidestepping: Implications for ACL injury risk. *Journal of Biomechanics*, *45*(8), 1491–1497. https://doi.org/10.1016/j.jbiomech.2012.02.010

Findley, T., Chaudhry, H., & Dhar, S. (2015). Transmission of muscle force to fascia during exercise. *Journal of Bodywork and Movement Therapies*, *19*(1), 119–123. https://doi.org/10.1016/j.jbmt.2014.08.010

Foley, R. C. A., Bulbrook, B. D., Button, D. C., & Holmes, M. W. R. (2017). Effects os a band loop on lower extremity muscle activity and kinematics during the barbell squat. *International Journal of Sports Physical Therapy*, *12*(4), 550–559. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/28900561%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC5534145

Ford, K., Nguyen, A.-D., Dischiavi, S., Hegedus, E., Zuk, E., & Taylor, J. (2015). An evidence-based review of hip-focused neuromuscular exercise interventions to address dynamic lower extremity valgus. *Open Access Journal of Sports Medicine*, 291. https://doi.org/10.2147/oajsm.s72432

Froehle, A. W., Grannis, K. A., Sherwood, R. J., & Duren, D. L. (2017). Relationships Between Age at Menarche, Walking Gait Base of Support, and Stance Phase Frontal Plane Knee Biomechanics in Adolescent Girls. *PM and R*, *9*(5), 444–454. https://doi.org/10.1016/j.pmrj.2016.07.532

Herman, D. C., Oñate, J. A., Weinhold, P. S., Guskiewicz, K. M., Garrett, W. E., Yu, B., … Saparon, A. (2008). Quadriceps Angle and Risk of Injury Among High School Cross-Country Runners. *American Journal of Sports Medicine*, *37*(2), 334–348. https://doi.org/10.1177/0363546507311602

Herrington, L., Nester, C., Horton, M. G., Hall, T. L., Mansour, E., Whiteside, L. A., … Marques,

A. P. (1989). Quadriceps Femoris Muscle Angle : Normal Values and Relationships with Gender and Selected Skeletal Measures. *Clinical Biomechanics*, *51*(2), 966–972. https://doi.org/10.1053/j.sart.2018.04.004

Hewett, T. E. (2017). Biomechanical Deficit Profiles Associated with ACL Injury Risk in Female Athletes, *48*(1), 107–113. https://doi.org/10.1249/MSS.0000000000000750.Biomechanical

Hewett, T. E., Ford, K. R., & Myer, G. D. (2006). Anterior cruciate ligament injuries in female athletes: Part 2, a meta-analysis of neuromuscular interventions aimed at injury prevention. *American Journal of Sports Medicine*, *34*(3), 490–498. https://doi.org/10.1177/0363546505282619

Hewett, T. E., Myer, G. D., & Ford, K. R. (2006). Anterior cruciate ligament injuries in female athletes: Part 1, mechanisms and risk factors. *American Journal of Sports Medicine*, *34*(2), 299–311. https://doi.org/10.1177/0363546505284183

Hickey Lucas, K. C., Kline, P. W., Ireland, M. L., & Noehren, B. (2017). Hip and trunk muscle dysfunction: implications for anterior cruciate ligament injury prevention. *Annals of Joint*, *2*, 18–18. https://doi.org/10.21037/aoj.2017.05.07

Horton, M. G., & Hall, T. L. (1989). Quadriceps Femoris Muscle Angle : Normal Values and Relationships with Gender and Selected Skeletal Measures. *Physical Therapy*, *69*(11), 897–901. https://doi.org/10.1093/ptj/69.11.897

Howard, J. S., Fazio, M. A., Mattacola, C. G., Uhl, T. L., & Jacobs, C. A. (2011). Structure, sex, and strength and knee and hip kinematics during landing. *Journal of Athletic Training*, *46*(4), 376–385. https://doi.org/10.4085/1062-6050-46.4.376

Howell, K. C. (2013). Training for landing and cutting stability in young female basketball and soccer players. *Strength and Conditioning Journal*, *35*(2), 66–78. https://doi.org/10.1519/SSC.0b013e31828b9a23

Ingber, D. E. (2003a). Tensegrity I. Cell structure and hierarchical systems biology. *Journal of Cell Science*, *116*(7), 1157–1173. https://doi.org/10.1242/jcs.00359

Ingber, D. E. (2003b). Tensegrity II. How structural networks influence cellular information processing networks. *Journal of Cell Science*, *116*(8), 1397–1408. https://doi.org/10.1242/jcs.00360

Ingber, D E. (1993). Cellular tensegrity: defining new rules of biological design that govern the cytoskeleton. *Journal of Cell Science*, *104 (Pt 3*, 613–627. https://doi.org/10.1242/jcs.00359

Ingber, Donald E., Wang, N., & Stamenović, D. (2014). Tensegrity, cellular biophysics, and the mechanics of living systems. *Reports on Progress in Physics*, *77*(4). https://doi.org/10.1088/0034-4885/77/4/046603

Jackson, K., Beach, T. A., & Andrews, D. M. (2017). The Effect of an Isometric Strength Training Protocol on Valgus Angle During a Drop-Jump Landing in Elite Female Volleyball Players. *International Journal of Kinesiology & Sports Science*, *5*(4), 1–9. https://doi.org/10.7575/aiac.ijkss.v.5n.4p.1

Jones, P. A., Herrington, L. C., Munro, A. G., & Graham-Smith, P. (2014). Is there a relationship between landing, cutting, and pivoting tasks in terms of the characteristics of dynamic valgus? *American Journal of Sports Medicine*, *42*(9), 2095–2102. https://doi.org/10.1177/0363546514539446

Kapandji A.I. (2011) Anatomia Funzionale: l'arto inferiore. Maloine- Monduzzi editoriale.

Koga, H., Nakamae, A., Shima, Y., Bahr, R., & Krosshaug, T. (2018). Hip and Ankle Kinematics in Noncontact Anterior Cruciate Ligament Injury Situations: Video Analysis Using Model-Based Image Matching. *American Journal of Sports Medicine*. https://doi.org/10.1177/0363546517732750

Krause, F., Wilke, J., Vogt, L., & Banzer, W. (2016). Intermuscular force transmission along myofascial chains: A systematic review. *Journal of Anatomy*, *228*(6), 910–918. https://doi.org/10.1111/joa.12464

LaBella, C. R., Hennrikus, W., & Hewett, T. E. (2014). Anterior Cruciate Ligament Injuries: Diagnosis, Treatment, and Prevention. *Pediatrics*, *133*(5), e1437–e1450. https://doi.org/10.1542/peds.2014-0623

Laboute, E., Savalli, L., Puig, P., Trouve, P., Sabot, G., Monnier, G., & Dubroca, B. (2010). Analyse de la reprise du sport et des ruptures itératives chez le sportif compétiteur pour 298 ligaments croisés antérieurs opérés avec le tendon rotulien ou les ischiojambiers. *Annals of Physical and Rehabilitation Medicine, 53*(10), 598–614. https://doi.org/10.1016/j.rehab.2010.10.002

Liebenson, C. (May 2017).Manuale Multidisciplinare per L'Allenamento Funzionale. Calzetti Mariucci Editori.

Lobietti , R., Coleman S., Pizzichillo E. & Merni F. (2010) Landing techniques in volleyball, Journal of Sports Sciences, 28:13, 1469-1476, DOI: 10.1080/02640414.2010.514278

Maas, H., & Sandercock, T. G. (2010). Force transmission between synergistic skeletal muscles through connective tissue linkages. *Journal of Biomedicine and Biotechnology, 2010*. https://doi.org/10.1155/2010/575672

Mall, N. A., Chalmers, P. N., Moric, M., Tanaka, M. J., Cole, B. J., Bach, B. R., & Paletta, G. A. (2014). Incidence and trends of anterior cruciate ligament reconstruction in the United States. *American Journal of Sports Medicine, 42*(10), 2363–2370. https://doi.org/10.1177/0363546514542796

Martin, C., Olivier, B., & Benjamin, N. (2016). The Functional Movement Screen in the Prediction of Injury in Adolescent Cricket Pace Bowlers: An Observational Study. *Journal of Sport Rehabilitation*, 1–30. https://doi.org/10.1123/jsr.2016-0073

Mayorga-Vega, D., Merino-Marban, R., & Viciana, J. (2014). Criterion-related validity of sit-and-reach tests for estimating hamstring and lumbar extensibility: A meta-analysis. *Journal of Sports Science and Medicine*, *13*(1), 1–14.

Mehl, J., Diermeier, T., Herbst, E., Imhoff, A. B., Stoffels, T., Zantop, T., … Achtnich, A. (2018). Evidence-based concepts for prevention of knee and ACL injuries. 2017 guidelines of the ligament committee of the German Knee Society (DKG). *Archives of Orthopaedic and Trauma Surgery*, *138*(1), 51–61. https://doi.org/10.1007/s00402-017-2809-5

Miyamoto, N., Hirata, K., Kimura, N., & Miyamoto-Mikami, E. (2018). Contributions of Hamstring Stiffness to Straight-Leg-Raise and Sit-and-Reach Test Scores. *International Journal of Sports Medicine*, *39*(2), 110–114. https://doi.org/10.1055/s-0043-117411

Mookerjee, S., & J.McMahon, M. (2014). Electromiographic analyisis of muscle activation during sit- and reach flexibility test. *The Journal of Strength & Conditioning Research*, 3496–3501.

Myer Gregory D, C., Brent CSCS, J. L., Ford Kevin R, F., & Hewett Timothy E, F. (2011). Real-Time Assessment and Neuromuscular Training Feedback Techniques to Prevent Anterior Cruciate Ligament Injury in Female Athletes. *Strength and Conditioning Journal*, *33*(3), 21–35.

Myers Thomas,(2014). Anatomy Trains, Myofascial Meridians for Manual and Movement Therapists, 3rd Edition. Churchill Livingstone.

Nakagawa, T. H., & Petersen, R. S. (2018). Relationship of hip and ankle range of motion, trunk muscle endurance with knee valgus and dynamic balance in males. *Physical Therapy in Sport*, *34*, 174–179. https://doi.org/10.1016/j.ptsp.2018.10.006

Nguyen, A., & Shultz, S. J. (2009). Identifying Reiationships Among Lower Extremity Alignment Characteristics. *Journal of Athletic Training*, *44*(5), 511–518. https://doi.org/10.4085/1062-6050-44.5.511

Obiettivi, C., Dell, O., Inferiore, A., Frosi, G., Sulli, A., Testa, M., … Ingber, D. E. (1993). Cellular tensegrity: defining new rules of biological design that govern the cytoskeleton. *Journal of Cell Science*, *104 (Pt 3*(4), 613–627. https://doi.org/10.1242/jcs.00359

Padua, D. A., DiStefano, L. J., Beutler, A. I., De La Motte, S. J., DiStefano, M. J., & Marshall, S. W. (2015). The landing error scoring system as a screening tool for an anterior cruciate ligament injury-prevention program in elite-youth soccer athletes. *Journal of Athletic Training*, *50*(6), 589–595. https://doi.org/10.4085/1062-6050-50.1.10

Palareti, G., Legnani, C., Cosmi, B., Antonucci, E., Erba, N., Poli, D., … Tosetto, A. (2016). Comparison between different D-Dimer cutoff values to assess the individual risk of recurrent venous thromboembolism: analysis of results obtained in the DULCIS study. *International Journal of Laboratory Hematology*, *38*(1), 42–49. https://doi.org/10.1111/ijlh.12426

Peterson Silveira, R., Stergiou, P., Carpes, F. P., Castro, F. A. d. S., Katz, L., & Stefanyshyn, D. J. (2017). Validity of a portable force platform for assessing biomechanical parameters in three different tasks. *Sports Biomechanics*, *16*(2), 177–186. https://doi.org/10.1080/14763141.2016.1213875

Piancino, M. G., Isola, G., Cannavale, R., Cutroneo, G., Vermiglio, G., Bracco, P., & Anastasi, G. P. (2017). From periodontal mechanoreceptors to chewing motor control: A systematic review. *Archives of Oral Biology*, *78*, 109–121. https://doi.org/10.1016/j.archoralbio.2017.02.010

Ratzlaff, C. R., Koehoorn, M., Cibere, J., & Kopec, J. A. (2012). Is Lifelong Knee Joint Force from Work, Home, and Sport Related to Knee Osteoarthritis? *International Journal of Rheumatology*, *2012*(1), 1–14. https://doi.org/10.1155/2012/584193

Ricard-Blum, S. (2011). The Collagen Family. *Cold Spring Harbor Perspectives in Biology*, *3*(1), 1–19. https://doi.org/10.1101/cshperspect.a004978

Salmon, L. J., Heath, E., Akrawi, H., Roe, J. P., Linklater, J., & Pinczewski, L. A. (2018). 20-Year Outcomes of Anterior Cruciate Ligament Reconstruction With Hamstring Tendon Autograft: The Catastrophic Effect of Age and Posterior Tibial Slope. *American Journal of Sports Medicine*, *46*(3), 531–543. https://doi.org/10.1177/0363546517741497

Savage, R. J., Lay, B. S., Wills, J. A., Lloyd, D. G., & Doyle, T. L. A. (2018). Prolonged running increases knee moments in sidestepping and cutting manoeuvres in sport. *Journal of Science and Medicine in Sport*, *21*(5), 508–512. https://doi.org/10.1016/j.jsams.2017.07.007

Scholtes, S. A., & Salsich, G. B. (2017). a Dynamic Valgus Index That Combines Hip and Knee Angles: Assessment of Utility in Females With Patellofemoral Pain. *International Journal of Sports Physical Therapy*, *12*(3), 333–340. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/28593087%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC5455183

Sharifi, M., Shirazi-Adl, A., & Marouane, H. (2017). Computational stability of human knee joint at early stance in Gait: Effects of muscle coactivity and anterior cruciate ligament deficiency. *Journal of Biomechanics*, *63*, 110–116. https://doi.org/10.1016/j.jbiomech.2017.08.004

Stanley, L. E., Kerr, Z. Y., Dompier, T. P., & Padua, D. A. (2016). Sex differences in the incidence of anterior cruciate ligament, medial collateral ligament, and meniscal injuries in collegiate and high school sports: 2009-2010 through 2013-2014. *American Journal of Sports Medicine*, *44*(6), 1565–1572. https://doi.org/10.1177/0363546516630927

Tate, J., & True, H. (2015). Expert Versus Novice Interrater and Intrarater Reliability of the Frontal Plane Projection Angle During a Single-Leg Squat, *20*(JulY), 23–27.

Thein, R., Hershkovich, O., Gordon, B., Burstein, G., Tenenbaum, S., Derazne, E., … Kreiss, Y. (2017). The Prevalence of Cruciate Ligament and Meniscus Knee Injury in Young Adults and Associations with Gender, Body Mass Index, and Height a Large Cross-Sectional Study. *Journal of Knee Surgery*, *30*(6), 565–570. https://doi.org/10.1055/s-0036-1593620

Tilp, M., & Rindler, M. (2013). Landing techniques in beach volleyball. *Journal of Sports Science and Medicine*, *12*(3), 447–453. https://doi.org/10.1080/02640414.2010.514278

Turkiewicz, A., Timpka, S., Thorlund, J. B., Ageberg, E., & Englund, M. (2017). Knee extensor strength and body weight in adolescent men and the risk of knee osteoarthritis by middle age. *Annals of the Rheumatic Diseases*, *76*(10), 1648–1656. https://doi.org/10.1136/annrheumdis-2016-210888

Ugalde, V., Brockman, C., Bailowitz, Z., & Pollard, C. D. (2015). Single Leg Squat Test and Its Relationship to Dynamic KneeValgus and Injury Risk Screening. *PM and R*, *7*(3), 229–235. https://doi.org/10.1016/j.pmrj.2014.08.361

Waldén, M., Krosshaug, T., Bjørneboe, J., Andersen, T. E., Faul, O., & Hägglund, M. (2015). Three distinct mechanisms predominate in noncontact anterior cruciate ligament injuries in male professional football players: A systematic video analysis of 39 cases. *British Journal of Sports Medicine*, *49*(22), 1452–1460. https://doi.org/10.1136/bjsports-2014-094573

Wilke, J., Vogt, L., Niederer, D., & Banzer, W. (2017). Is remote stretching based on myofascial chains as effective as local exercise? A randomised-controlled trial. *Journal of Sports Sciences*, *35*(20), 2021–2027. https://doi.org/10.1080/02640414.2016.1251606

Wilke, Jan, Krause, F., Vogt, L., & Banzer, W. (2016). What is evidence-based about myofascial chains: A systematic review. *Archives of Physical Medicine and Rehabilitation*, *97*(3), 454–461. https://doi.org/10.1016/j.apmr.2015.07.023

Wilke, Jan, Niederer, D., Vogt, L., & Banzer, W. (2016). Remote effects of lower limb stretching: preliminary evidence for myofascial connectivity? *Journal of Sports Sciences*, *34*(22), 2145–2148. https://doi.org/10.1080/02640414.2016.1179776

Wilke, Jan, Schleip, R., Yucesoy, C. A., & Banzer, W. (2017). Not merely a protective packing organ? A review of fascia and its force transmission capacity. *Journal of Applied Physiology*, jap.00565.2017. https://doi.org/10.1152/japplphysiol.00565.2017

Zahradnik, D., Jandacka, D., Uchytil, J., Farana, R., & Hamill, J. (2014). Lower extremity mechanics during landing after a volleyball block as a risk factor for. *Physical Therapy in Sport*. https://doi.org/10.1016/j.ptsp.2014.04.003

APPENDIX

CONSENTIMENTO INFORMADO, ESCLARECIDO E LIVRE PARA PARTICIPAÇÃO EM ESTUDOS DE INVESTIGAÇÃO (de acordo com a Declaração de Helsínquia e a Convenção de Oviedo)

Título do estudo: Tecido conjuntivo e influência no movimento: um estudo sobre a flexibilidade e a mobilidade do joelho valgo dinâmico

Enquadramento: Esta investigação está a ser realizada para a conclusão de Mestrado em Biocinética da Universidade de Coimbra, sob orientação da Professora Doutora Ana Faro e da Professora Doutora Beatriz Gomes. Este estudo realizar-se-á no Clube de Voleibol da Lousã, e a recolha de dados ocorrerá nos meses de novembro e dezembro de 2018. Será solicitado aos participantes no estudo que preencham um questionário e serão sujeitos a recolha de dados antropométricos (estatura, massa corporal, comprimento dos membros, entre outros). Para além disso, os participantes realizarão três avaliações: 1) protocolo de mobilidade Fms (Gray Cook), 2) teste de flexibilidade *seat and reach*, e 3) avaliação cinética (plataforma de forças) e cinemática (análise vídeo) dos exercícios *single leg squat* e *single leg landing*.

Condições e financiamento: A participação no estudo é voluntario e ausente de prejuizos assistenciais ou outros.

Confidencialidade e anonimato: É garantido que os dados retirados serão mantidos em anonimato e serão apenas utilizados para o presente estudo.

Espero poder contar com a vossa colaboração e grato pela atenção dada, Matteo Marescotti, estudante, Universidade de Coimbra, telem: +393280543354/+351913119916 , email: matteo.marescotti10@gmail.com. /mare_10@hotmail.it .

Por favor, leia com atenção a seguinte informação. Se achar que algo está incorreto ou que não está claro, não hesite em solicitar mais informações. Se concorda com a proposta que lhe foi feita, queira assinar, por favor, este documento.

_

Declaro ter lido e compreendido este documento, bem como as informações verbais que me foram fornecidas pela/s pessoa/s que acima assina/m. Foi-me garantida a possibilidade de, em qualquer altura, recusar participar neste estudo sem qualquer tipo de consequências. Desta forma, aceito participar neste estudo e permito a utilização dos dados que de forma voluntária forneço, confiando em que apenas serão utilizados para esta investigação e nas garantias de confidencialidade e anonimato que me são dadas pelo/a investigador/a.

Nome: ____

Assinatura:_________________________________ Data:____ /____ /________

SE NÃO FOR O PRÓPRIO A ASSINAR POR IDADE OU INCAPACIDADE

(se o menor tiver discernimento deve também assinar em cima, se consentir)

NOME:____

____

BI/CC N.º:______________________ DATA OU VALIDADE____ /____/______

GRAU DE PARENTESCO OU TIPO DE REPRESENTAÇÃO: _____________

ASSINATURA____

ESTE DOCUMENTO É COMPOSTO DE 2 PÁGINAS E FEITO EM DUPLICADO: UMA VIA PARA O INVESTIGADOR, OUTRA PARA A PESSOA QUE CONSENTE

APPENDIX B

ANTHROPOMETRIC AND GENERAL INFORMATION							
subject	age	age of volleyball practice	weekly time spent in practice	weight	height	leg dominance	body max index
1	13	8,00	6,00	55,30	162,50	1,00	20,94
2	13	8,00	6,00	55,30	165,00	1,00	20,31
3	13	8,00	6,00	58,20	162,00	1,00	22,18
4	12	5,00	6,00	47,20	155,30	2,00	19,57
5	14	3,00	6,00	66,70	169,60	1,00	23,19
6	14	3,00	6,00	61,20	167,40	1,00	21,84
7	13	3,00	4,00	53,40	158,40	2,00	21,28
8	13	3,00	4,00	58,60	163,30	1,00	21,97
9	13	5,00	6,00	52,30	165,60	1,00	19,07
10	13	2,00	6,00	50,20	162,00	2,00	19,13
11	13	2,00	4,00	50,30	156,20	1,00	20,62
12	15	8,00	4,00	48,00	156,00	1,00	19,72
13	14	7,00	4,00	50,20	164,70	1,00	18,51
14	16	5,00	6,00	59,60	176,30	1,00	19,18
15	14	6,00	6,00	50,10	158,20	1,00	20,02
16	14	5,00	6,00	56,50	164,80	1,00	20,80
17	15	4,00	6,00	57,70	171,30	1,00	19,66
18	15	4,00	6,00	55,60	165,60	1,00	20,27
19	16	5,00	6,00	48,80	157,60	1,00	19,65
20	17	7,00	6,00	47,80	159,60	1,00	18,77
21	17	6,00	6,00	56,60	156,80	1,00	23,02
22	16	2,00	6,00	70,70	179,30	1,00	21,99

23	17	4,00	6,00	59,80	160,20	1,00	23,30
media	14,35	4,91	5,57	55,22	163,38	1,13	20,65
s.d	1,53	2,04	0,84	6,04	6,33	0,34	1,46

QUALITY OF MOVEMENT													
MOBILITY													FLEXIBLITY
FUNCTIONAL MOVEMENT SCREEN													
REACHING		LEG RAISING		ROTARY STABILITY		LUNGING		STEPPING		SQUAT	PUSH UP	TOTAL SCORE	SIT AND REACH
left	right	left	right	left	right	left	right	left	right				sit and reach score
3	3	3	3	2	2	3	3	3	3	2	2	18	21
3	3	3	3	3	3	2	1	3	3	1	1	15	31
2	2	1	3	2	2	2	2	2	2	2	2	13	21
3	3	1	2	3	3	2	2	2	2	1	1	13	30
2	3	2	3	2	1	2	3	3	3	2	1	13	34
2	3	2	2	2	2	2	2	2	2	2	2	14	26
2	3	2	1	2	2	2	2	2	2	1	1	11	21
3	3	2	2	2	2	2	2	2	3	2	2	17	19
3	3	2	2	2	1	2	2	2	1	1	1	11	29
3	3	2	1	3	3	3	3	2	2	2	2	16	17
3	3	3	3	2	2	2	2	2	2	1	1	17	27
3	3	3	3	3	3	3	3	3	2	3	3	20	36
3	3	3	3	3	2	2	2	2	2	3	1	16	34
2	3	3	3	3	3	2	2	3	3	2	2	17	27

2	2	2	2	3	2	3	3	2	2	3	2	16	37
3	3	2	2	2	2	2	2	3	2	2	1	14	24
1	2	2	2	2	2	3	3	1	2	3	2	14	33
3	3	3	3	2	3	3	2	3	2	2	3	17	27
3	3	3	3	3	2	1	2	2	1	2	1	13	33
3	2	2	2	2	2	2	3	1	2	2	2	13	23
3	3	3	3	2	2	2	2	3	3	2	1	16	27
2	2	3	2	2	2	2	2	2	2	2	1	16	30
3	3	2	3	2	2	2	2	3	3	2	2	19	25
2,61	2,78	2,35	2,43	2,35	2,17	2,22	2,26	2,30	2,22	1,96	1,61	15,17	27,48
0,58	0,42	0,65	0,66	0,49	0,58	0,52	0,54	0,63	0,60	0,64	0,66	2,39	5,58

SINGLE LEG SQUAT														
VIDEO ANALYSIS														
ANGLE ANALYSIS								TIME ANALYSIS						
q angle			hip angle adduction			Scholtes and Salsich Valgum index		phases		total time	angle peak		phases angle peak	
start	peak dynamic valg	angle amplitude	start	adduction peak	angle amplitude	knee	hip	eccentric	concentric		knee	hip	knee	hip

	um moment													
175,00	170,80	4,20	88,90	81,90	7,00	9,20	8,10	1,04	1,24	2,28	1,08	1,08	2,00	2,00
178,80	168,60	10,20	83,90	78,10	5,80	11,40	11,90	1,44	0,80	2,24	1,64	1,40	2,00	1,00
172,70	160,20	12,50	82,50	79,20	3,30	19,80	10,80	1,60	1,04	2,64	2,04	1,56	2,00	2,00
175,30	160,00	15,30	88,80	83,50	5,30	20,00	6,50	1,20	1,40	2,60	0,96	1,68	1,00	2,00
174,70	174,50	0,20	85,80	71,10	14,70	5,50	18,90	0,64	0,72	1,36	0,64	0,56	1,00	1,00
176,90	169,30	7,60	82,40	69,00	13,40	10,70	21,00	0,84	1,08	1,92	0,68	0,92	1,00	2,00
178,90	148,10	30,80	85,90	68,60	17,30	31,90	21,40	1,56	1,00	2,56	1,64	1,52	2,00	1,00
175,20	167,30	7,90	82,80	76,70	6,10	12,70	13,30	1,24	1,34	2,58	1,08	1,28	1,00	2,00
173,10	159,00	14,10	79,80	69,90	9,90	21,00	20,10	0,96	1,04	2,00	0,88	0,96	1,00	1,00
170,90	162,00	8,90	82,10	72,80	9,30	18,00	17,20	1,44	0,84	2,28	1,36	1,24	1,00	1,00
174,70	168,90	5,80	85,60	77,90	7,70	11,10	12,10	1,48	1,20	2,68	1,16	1,32	1,00	1,00
178,50	169,90	8,60	86,50	77,20	9,30	10,10	12,80	1,64	1,16	2,80	1,68	1,56	2,00	1,00
178,80	168,00	10,80	86,60	78,30	8,30	12,00	11,70	1,40	1,24	2,64	1,28	1,36	1,00	1,00
176,90	172,00	4,90	84,70	78,90	5,80	8,00	11,10	1,24	1,28	2,52	1,40	1,20	2,00	1,00

175,60	168,90	6,70	85,80	79,90	5,90	11,10	10,10	1,36	1,20	2,56	1,40	1,80	1,00	2,00
176,10	172,50	3,60	83,30	70,00	13,30	7,50	20,00	1,04	2,04	3,08	1,92	0,96	2,00	1,00
177,10	161,30	15,80	86,60	74,00	12,60	18,70	16,00	1,68	1,12	2,80	1,84	1,92	2,00	2,00
174,30	168,30	6,00	85,00	81,90	3,10	11,70	8,10	1,24	1,00	2,24	1,20	1,32	1,00	2,00
177,80	167,50	10,30	86,10	72,50	13,60	12,50	17,50	1,84	1,64	3,48	2,12	2,00	2,00	2,00
173,00	145,10	27,90	84,80	64,00	20,80	34,90	26,00	1,24	1,08	2,32	1,36	1,32	2,00	2,00
175,10	169,20	5,90	78,80	77,40	1,40	10,80	12,60	1,20	1,32	2,52	0,88	0,72	1,00	1,00
170,30	162,60	7,70	83,60	75,70	7,90	17,40	14,30	1,32	1,16	2,48	1,24	1,20	1,00	1,00
168,80	168,50	0,30	81,80	78,60	3,20	11,50	11,40	1,24	1,16	2,40	1,16	1,52	1,00	2,00
175,15	165,33	9,83	84,44	75,53	8,91	14,67	14,47	1,30	1,18	2,48	1,33	1,32	1,43	1,48
2,76	7,29	7,41	2,54	5,00	4,92	7,29	5,00	0,28	0,27	0,41	0,41	0,36	0,51	0,51

FORCE PLATFORM											
MAXIMAL FORCE			MINIMAL FORCE			FORCE DIFFERENCE			TIME		
X	Y	Z	X	Y	Z	X	Y	Z	START	END	CONTACT TIME
945,35	98,89	4278,21	-75,62	-259,92	145,52	1020,97	358,81	4132,69	3,63	8,00	4,37
732,65	170,11	2505,36	-3,55	-114,19	-0,78	736,20	284,30	2506,14	2,98	4,98	2,00
1137,69	239,75	2140,02	-247,81	-186,51	16,60	1385,50	426,25	2123,41	2,96	4,46	1,50
607,89	155,74	3079,52	-60,22	-112,67	12,51	668,11	268,40	3067,02	2,74	4,68	1,94
1024,70	106,32	5266,43	-20,68	-303,23	270,70	1045,38	409,55	4995,73	3,23	8,00	4,77

728,91	118,36	2986,26	-60,88	-100,53	-3,85	789,79	218,89	2990,11	2,98	4,98	2,00
775,28	106,99	2425,19	-62,05	-181,78	-7,07	837,33	288,77	2432,25	1,80	4,47	2,67
1013,64	80,78	3419,24	-212,17	-149,48	10,73	1225,81	230,26	3408,51	3,65	5,86	2,21
559,35	49,54	2239,21	-3,55	-114,19	-0,78	562,90	163,73	2239,99	2,98	4,98	2,00
862,08	71,07	4348,56	-51,39	-145,99	29,71	913,47	217,06	4318,85	2,33	8,00	5,67
543,58	79,88	2217,53	-51,39	-145,99	29,71	594,97	225,87	2187,82	3,17	6,45	3,28
840,71	32,21	1911,88	-133,72	-118,70	12,16	974,43	150,91	1899,72	3,58	6,93	3,35
664,97	176,23	4988,95	-24,95	-511,18	10,92	689,93	687,41	4978,03	3,76	6,54	2,78
731,70	137,76	3058,78	-93,11	-76,25	14,65	824,81	214,00	3044,13	2,51	6,46	3,96
1137,69	239,75	2140,02	-247,81	-186,51	16,60	1385,50	426,25	2123,41	2,96	4,46	1,50
1272,98	76,38	3079,57	-51,41	-197,90	12,86	1324,39	274,28	3066,71	3,84	7,92	4,08

988,25	164,70	2092,67	-71,93	-64,26	28,46	1060,18	228,96	2064,21	3,32	4,99	1,67
745,81	37,97	3915,31	-87,70	-168,48	10,28	833,51	206,45	3905,03	3,60	7,87	4,27
883,69	231,21	2160,20	-152,92	-85,03	14,82	1036,61	316,24	2145,39	1,51	3,31	1,80
1010,27	157,74	3545,99	-23,06	-168,42	4,12	1033,33	326,16	3541,87	2,94	8,00	5,06
813,74	80,10	3246,69	-19,47	-74,63	13,35	833,21	154,72	3233,34	3,49	6,62	3,13
1476,69	149,52	5111,46	-173,85	-198,23	-5,42	1650,54	347,75	5116,88	3,00	6,53	3,53
1073,24	85,92	3720,71	-41,33	-182,25	3,36	1114,58	268,17	3717,35	3,05	8,00	4,95
894,39	123,78	3212,08	-85,68	-167,23	27,79	980,06	291,01	3184,29	3,04	6,19	3,15
232,15	61,30	1040,87	74,02	95,18	60,81	276,77	118,47	1014,32	0,59	1,49	1,29

APPENDIX C

<table>
<tr><td colspan="5" rowspan="7">ANTHROPOMETRIC AND GENERAL INFORMATION</td><td colspan="2">age</td></tr>
<tr><td colspan="2">age of volleyball practice</td></tr>
<tr><td colspan="2">weekly time spent in practice</td></tr>
<tr><td colspan="2">weight</td></tr>
<tr><td colspan="2">height</td></tr>
<tr><td colspan="2">b.m.i</td></tr>
<tr><td colspan="2">dominance</td></tr>
<tr><td rowspan="14">QUALITY OF MOVEMENT</td><td rowspan="13">MOBILITY</td><td rowspan="13">FUNCTIONAL MOVEMENT SCREEN</td><td colspan="2" rowspan="2">REACHING</td><td colspan="2">left</td></tr>
<tr><td colspan="2">right</td></tr>
<tr><td colspan="2" rowspan="2">LEG RAISING</td><td colspan="2">left</td></tr>
<tr><td colspan="2">right</td></tr>
<tr><td colspan="2" rowspan="2">ROTARY STABILITY</td><td colspan="2">left</td></tr>
<tr><td colspan="2">right</td></tr>
<tr><td colspan="2" rowspan="2">LUNGING</td><td colspan="2">left</td></tr>
<tr><td colspan="2">right</td></tr>
<tr><td colspan="2" rowspan="2">STEPPING</td><td colspan="2">left</td></tr>
<tr><td colspan="2">right</td></tr>
<tr><td colspan="4">SQUAT</td></tr>
<tr><td colspan="4">PUSH UP</td></tr>
<tr><td colspan="4">TOTAL SCORE</td></tr>
<tr><td colspan="2">FLEXIBLITY</td><td colspan="2">SIT AND REACH</td><td colspan="2">sit and reach score</td></tr>
<tr><td rowspan="5">BIOMECHANIC ANALYSIS</td><td colspan="2" rowspan="5">SINGLE LEG SQUAT</td><td rowspan="5">VIDEO ANALYSIS</td><td rowspan="5">ANGLE ANALYSIS</td><td rowspan="3">q angle</td><td>start</td></tr>
<tr><td>peak dynamic valgum moment</td></tr>
<tr><td>angle amplitude</td></tr>
<tr><td rowspan="2">hip angle adduction</td><td>start</td></tr>
<tr><td>adduction peak</td></tr>
</table>

					angle amplitude
				Scholtes and Salsich Valgum index	knee
					hip
			TIME ANALYSIS	phases	eccentric
					concentric
				total time	
				angle peak	knee
					hip
				phases	knee
					hip
	FORCE PLATFORM	MAXIMAL MOMENT	X		
			Y		
			Z		
		MINIMAL MOMENT	X		
			Y		
			Z		
		MOMENT DIFFERENCE	X		
			Y		
			Z		
		TIME	START		
			END		
			CONTACT TIME		

SINGLE LEG SQUAT														
VIDEO ANALYSIS														
ANGLE ANALYSIS								TIME ANALYSIS						
q angle			hip angle adduction			Scholtes and Salsich Valgum index		phases		total time	angle peak		phases	
start	peak dynamic valgum moment	angle amplitude	start	adduction peak	angle amplitude	knee	hip	eccentric	concentric		knee	hip	knee	hip
-0,221	0,019	-0,101	-0,253	-0,173	0,045	-0,019	0,173	0,090	0,151	0,162	0,071	-0,001	0,089	0,068

0,325	0,020	0,102	0,180	0,257	-0,168	-0,020	-0,257	0,171	0,087	0,175	0,324	0,169	0,521	0,129
-0,403	0,066	-0,215	-0,221	-0,023	-0,091	-0,066	0,023	-0,317	-0,019	-0,229	-0,047	-0,129	0,037	0,294
-0,318	0,301	-0,414	-0,294	-0,037	-0,114	-0,301	0,037	-0,429	-0,179	-0,412	-0,267	-0,469	-0,172	-0,105
-0,131	0,179	-0,224	-0,107	-0,097	0,044	-0,179	0,097	-0,290	-0,165	-0,308	-0,099	-0,299	-0,004	-0,199
-0,332	0,278	-0,397	-0,365	0,061	-0,250	-0,278	-0,061	-0,339	-0,089	-0,291	-0,296	-0,398	-0,248	0,061
0,070	-0,187	0,210	0,041	0,021	0,000	0,187	-0,021	0,287	0,497	0,528	0,136	0,330	-0,079	-0,112
-0,108	0,104	-0,143	-0,121	0,146	-0,211	-0,104	-0,146	-0,063	0,251	0,124	-0,139	-0,153	-0,167	-0,106
0,275	0,422	-0,312	-0,047	0,104	-0,130	-0,422	-0,104	-0,271	0,114	-0,108	-0,320	-0,358	-0,176	-0,339
0,279	0,414	-0,303	0,080	0,181	-0,143	-0,414	-0,181	0,162	0,044	0,140	0,004	-0,128	0,072	-0,389
0,119	0,594	-0,539	0,103	0,499	-0,454	-0,594	-0,499	0,002	0,044	0,031	-0,007	-0,072	0,088	0,029
0,385	0,183	-0,037	0,331	0,317	-0,152	-0,183	-0,317	0,388	0,045	0,295	0,269	0,433	0,096	-0,151

0,180	0,065	0,003	0,238	0,462	-0,347	-0,065	-0,462	0,395	0,002	0,271	0,267	0,350	0,196	0,013
-0,069	0,085	-0,109	0,228	0,308	-0,196	-0,085	-0,308	0,020	-0,310	-0,193	-0,047	0,076	-0,030	0,104
-0,149	-0,093	0,036	0,330	-0,174	0,347	0,093	0,174	-0,058	-0,156	-0,144	-0,056	0,035	0,065	0,186
0,053	0,694	-0,662	-0,106	0,407	-0,469	-0,694	-0,407	-0,330	0,071	-0,178	-0,161	-0,433	-0,006	-0,329
-0,059	0,393	-0,408	-0,042	0,344	-0,371	-0,393	-0,344	-0,339	-0,196	-0,362	-0,329	-0,382	-0,026	-0,058
0,112	0,282	-0,235	0,167	0,099	-0,014	-0,282	-0,099	0,188	0,119	0,207	0,217	0,215	0,061	0,206
-0,111	0,069	-0,109	0,089	0,219	-0,177	-0,069	-0,219	0,122	-0,200	-0,051	0,086	0,211	0,125	0,448
-0,139	0,555	-0,597	0,080	0,576	-0,545	-0,555	-0,576	0,103	0,048	0,102	-0,091	0,023	-0,077	0,003
0,392	0,327	-0,176	0,323	0,172	-0,008	-0,327	-0,172	0,110	0,002	0,077	0,031	0,247	-0,077	-0,116
1,000	0,144	0,231	0,429	-0,021	0,243	-0,144	0,021	0,241	0,174	0,281	0,278	0,192	0,431	-0,160
0,144	1,000	-0,929	0,004	-0,464	-0,470	-1,000	-0,464	-0,274	0,221	-0,039	-0,176	-0,287	-0,212	-0,139

0,231	-0,929	1,000	0,156	0,464	0,553	0,929	0,464	0,359	-0,153	0,143	0,277	0,353	0,369	0,077
0,429	0,004	0,156	1,000	0,287	0,225	-0,004	-0,287	0,215	0,076	0,198	0,186	0,448	0,311	0,234
-0,021	0,464	-0,464	0,287	1,000	-0,869	-0,464	-1,000	0,165	0,041	0,140	-0,049	0,251	-0,195	0,185
0,243	-0,470	0,553	0,225	-0,869	1,000	0,470	0,869	-0,057	-0,002	-0,040	0,146	-0,024	0,359	-0,068
-0,144	-1,000	0,929	-0,004	-0,464	0,470	1,000	0,464	0,274	-0,221	0,039	0,176	0,287	0,212	0,139
0,021	-0,464	0,464	-0,287	-1,000	0,869	0,464	1,000	-0,165	-0,041	-0,140	0,049	-0,251	0,195	-0,185
0,241	-0,274	0,359	0,215	0,165	-0,057	0,274	-0,165	1,000	0,097	0,747	0,779	0,820	0,425	0,073
0,174	0,221	-0,153	0,076	0,165	-0,002	-0,221	-0,041	0,097	1,000	0,734	0,331	0,139	0,201	0,110
0,281	-0,039	0,143	0,198	0,041	-0,040	0,039	-0,140	0,747	0,734	1,000	0,753	0,652	0,424	0,123
0,278	-0,176	0,277	0,186	-0,049	0,146	0,176	0,049	0,779	0,331	0,753	1,000	0,654	0,742	0,058
0,192	-0,287	0,353	0,448	0,251	-0,024	0,287	-0,251	0,820	0,139	0,652	0,654	1,000	0,325	0,461

0,431	-0,212	0,369	0,311	-0,195	0,359	0,212	0,195	0,425	0,201	0,424	0,742	0,325	1,000	0,038
-0,160	-0,139	0,077	0,234	0,185	-0,068	0,139	-0,185	0,073	0,110	0,123	0,058	0,461	0,038	1,000
-0,411	0,025	-0,178	-0,089	-0,120	0,076	-0,025	0,120	-0,007	0,210	0,135	0,292	0,018	0,145	0,166
0,167	-0,161	0,220	0,270	0,084	0,054	0,287	-0,165	0,378	0,067	0,303	0,433	0,533	0,260	0,362
-0,383	0,165	-0,305	0,037	0,033	-0,015	0,161	-0,033	-0,495	-0,191	-0,465	-0,488	-0,513	-0,424	-0,159
0,074	-0,062	0,088	-0,102	-0,306	0,259	-0,165	0,306	-0,381	-0,177	-0,378	-0,374	-0,451	-0,071	-0,408
-0,022	-0,115	0,105	-0,286	-0,083	-0,063	0,062	0,083	0,207	0,074	0,191	0,143	0,193	0,207	0,164
-0,041	0,363	-0,372	0,313	0,005	0,156	0,115	-0,005	-0,493	-0,277	-0,521	-0,348	-0,438	-0,054	-0,068
-0,365	0,038	-0,173	-0,047	-0,019	-0,005	-0,363	0,019	0,096	0,223	0,215	0,345	0,136	0,140	0,249
0,104	0,009	0,030	0,369	0,110	0,079	-0,038	-0,110	0,030	-0,025	0,004	0,109	0,120	-0,031	0,055
-0,391	0,148	-0,291	0,019	0,034	-0,025	-0,009	-0,034	-0,478	-0,179	-0,446	-0,479	-0,500	-0,432	-0,159

-0,037	0,422	-0,429	-0,047	0,286	-0,315	-0,422	-0,286	-0,329	0,116	-0,184	-0,286	-0,395	-0,210	-0,023
-0,429	0,218	-0,374	-0,062	-0,019	-0,012	-0,218	0,019	-0,436	-0,072	-0,345	-0,318	-0,538	-0,147	-0,212
-0,479	0,059	-0,237	-0,050	-0,153	0,130	-0,059	0,153	-0,329	-0,136	-0,316	-0,237	-0,442	-0,074	-0,234

FORCE PLATFORM											
MAXIMAL MOMENT			MINIMAL MOMENT			MOMENT DIFFERENCE			TIME		
X	Y	Z	X	Y	Z	X	Y	Z	START	END	CONTACT TIME
0,322	0,022	0,134	0,052	0,161	-0,152	0,256	-0,118	0,147	-0,019	0,283	0,336
-0,046	0,306	-0,247	-0,052	-0,149	-0,040	-0,025	0,278	-0,251	0,249	-0,071	-0,196
0,294	0,251	0,114	0,081	0,307	0,146	0,225	-0,117	0,108	-0,136	0,052	0,123
0,524	-0,057	0,455	-0,104	-0,063	0,316	0,468	0,021	0,448	0,187	0,191	0,136
0,333	0,037	0,420	-0,007	-0,084	0,142	0,281	0,087	0,422	0,117	0,143	0,112
0,412	-0,141	0,214	-0,133	0,007	0,315	0,381	-0,079	0,201	0,170	0,137	0,081
-0,028	-0,102	-0,219	-0,074	0,114	-0,485	-0,004	-0,144	-0,196	0,025	-0,085	-0,109

-0,316	-0,399	0,119	0,294	-0,118	-0,140	-0,343	-0,112	0,131	0,175	0,336	0,309
-0,594	-0,585	0,107	0,489	-0,036	0,139	-0,629	-0,273	0,101	0,008	0,183	0,208
-0,158	-0,220	0,167	0,168	-0,085	-0,007	-0,177	-0,045	0,172	0,141	0,236	0,208
-0,131	0,068	0,034	0,017	-0,163	0,272	-0,114	0,166	0,019	0,338	0,148	0,016
-0,279	0,341	-0,135	-0,104	-0,012	-0,171	-0,206	0,186	-0,128	-0,315	-0,263	-0,161
-0,218	-0,059	-0,116	-0,067	0,290	-0,392	-0,165	-0,264	-0,096	-0,088	0,061	0,111
0,062	-0,294	0,039	-0,103	-0,021	0,128	0,080	-0,135	0,033	0,401	0,351	0,223
0,257	-0,058	0,146	-0,121	-0,114	0,472	0,248	0,062	0,121	0,106	0,352	0,358
-0,024	-0,424	0,197	0,163	-0,069	0,380	-0,064	-0,164	0,184	0,286	0,405	0,338
0,137	-0,173	0,367	0,122	-0,099	0,300	0,082	-0,010	0,354	0,364	0,441	0,032
0,401	0,203	0,129	-0,369	-0,284	0,073	0,435	0,333	0,128	0,362	0,170	0,216

0,084	-0,223	-0,105	-0,345	0,180	-0,089	0,162	-0,260	-0,103	0,243	0,283	0,216
0,092	-0,333	0,188	-0,172	-0,074	-0,015	0,123	-0,112	0,194	0,459	0,496	0,363
-0,075	0,291	-0,142	-0,024	-0,098	0,113	-0,057	0,230	-0,152	0,084	-0,281	-0,363
-0,411	0,167	-0,383	0,074	-0,022	-0,041	-0,365	0,104	-0,391	-0,037	-0,429	-0,479
0,025	-0,161	0,165	-0,062	-0,115	0,363	0,038	0,009	0,148	0,422	0,218	0,059
-0,178	0,220	-0,305	0,088	0,105	-0,372	-0,173	0,030	-0,291	-0,429	-0,374	-0,237
-0,089	0,270	0,037	-0,102	-0,286	0,313	-0,047	0,369	0,019	-0,047	-0,062	-0,050
-0,120	0,084	0,033	-0,306	-0,083	0,005	-0,019	0,110	0,034	0,286	-0,019	-0,153
0,076	0,054	-0,015	0,259	-0,063	0,156	-0,005	0,079	-0,025	-0,315	-0,012	0,130
-0,025	0,287	0,161	-0,165	0,062	0,115	-0,363	-0,038	-0,009	-0,422	-0,218	-0,059
0,120	-0,165	-0,033	0,306	0,083	-0,005	0,019	-0,110	-0,034	-0,286	0,019	0,153

-0,007	0,378	-0,495	-0,381	0,207	-0,493	0,096	0,030	-0,478	-0,329	-0,436	-0,329
0,210	0,067	-0,191	-0,177	0,074	-0,277	0,223	-0,025	-0,179	0,116	-0,072	-0,136
0,135	0,303	-0,465	-0,378	0,191	-0,521	0,215	0,004	-0,446	-0,184	-0,345	-0,316
0,292	0,433	-0,488	-0,374	0,143	-0,348	0,345	0,109	-0,479	-0,286	-0,318	-0,237
0,018	0,533	-0,513	-0,451	0,193	-0,438	0,136	0,120	-0,500	-0,395	-0,538	-0,442
0,145	0,260	-0,424	-0,071	0,207	-0,054	0,140	-0,031	-0,432	-0,210	-0,147	-0,074
0,166	0,362	-0,159	-0,408	0,164	-0,068	0,249	0,055	-0,159	-0,023	-0,212	-0,234
1,000	0,255	0,267	-0,501	-0,121	0,116	0,973	0,229	0,267	0,141	0,210	0,178
0,255	1,000	-0,178	-0,443	-0,104	-0,086	0,332	0,601	-0,177	-0,379	-0,596	-0,516
0,267	-0,178	1,000	0,238	-0,633	0,460	0,160	0,417	0,999	0,273	0,648	0,624
-0,501	-0,443	0,238	1,000	-0,089	0,160	-0,688	-0,158	0,235	0,084	0,375	0,395

-0,121	-0,104	-0,633	-0,089	1,000	-0,360	-0,077	-0,857	-0,628	-0,356	-0,337	-0,227
0,116	-0,086	0,460	0,160	-0,360	1,000	0,055	0,244	0,412	0,179	0,375	0,352
0,973	0,332	0,160	-0,688	-0,077	0,055	1,000	0,234	0,161	0,096	0,076	0,044
0,229	0,601	0,417	-0,158	-0,857	0,244	0,234	1,000	0,413	0,090	-0,038	-0,085
0,267	-0,177	0,999	0,235	-0,628	0,412	0,161	0,413	1,000	0,269	0,642	0,619
0,141	-0,379	0,273	0,084	-0,356	0,179	0,096	0,090	0,269	1,000	0,517	0,140
0,210	-0,596	0,648	0,375	-0,337	0,375	0,076	-0,038	0,642	0,517	1,000	0,920
0,178	-0,516	0,624	0,395	-0,227	0,352	0,044	-0,085	0,619	0,140	0,920	1,000

	QUALITY OF MOVEMENT													
	MOBILITY													FLEXIBLITY
	FUNCTIONAL MOVEMENT SCREEN													
	REACHING		LEG RAISING		ROTARY STABILITY		LUNGING		STEPPING		SQUAT	PUSH UP	TOTAL SCORE	SIT AND REACH
	left	right	left	right	left	right	left	right	left	right				sit and reach score
age of practising	0,237	-0,128	0,093	0,366	0,306	0,168	0,104	0,021	0,197	0,090	0,241	0,177	0,106	0,211
age	-0,044	-0,230	0,378	0,293	-0,109	-0,020	-0,157	0,105	0,073	0,112	0,390	0,187	0,270	0,188

Correlation F.M.S simmetry			
	Scholtes and Salsich Valgum index		
	knee	hip	sit and reach score
REACHING	0,301	#N/D	-0,016
LEG RAISING	0,284	-0,016	-0,248
ROTARY STABILITY	-0,171	#N/D	####

LUNGING	0,039	0,216	####
STEPPING	0,180	0,325	####

Scholtes and Salsich Valgum index			
	knee	hip	sit and reach score
TOTAL REACHING	-0,268	-0,144	-0,195
TOTAL LEG RAISING	-0,587	-0,397	0,379
TOTAL R. STABILITY	-0,134	-0,444	0,174
TOTAL LUNGING	0,006	-0,069	0,049

TOTAL STEPPING	-0,625	-0,429	-0,088

	Scholtes and Salsich Valgum index		MAXIMAL FORCE		
			X	Y	Z
	knee	hip			
14 PARAMETERS	- 0,440	- 0,600	-0,02	-0,25	0,27