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Faculty of Sport Sciences and Physical Education
Faculdade de Ciências do Desporto e Educação Física
UNIVERSITY OF COIMBRA
UNIVERSIDADE DE COIMBRA

Analysis of the relationships between the anthropometric characteristics of young kayakers, the paddle set-up and the performance

Master in Sport Training for Children and Youth
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RUI ANTÓNIO DE ALMEIDA DUARTE FERNANDES

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Thesis submitted to the Faculty of Sport Sciences and Physical Education, University of Coimbra, in order to achieve the degree of Master of Sports Training for Children and Youth, in Sport Sciences, in the specialty of Sports Training.

Supervisors: PhD Amândio Cupido Santos and MSc Beatriz Branquinho Gomes

Monografia apresentada à Faculdade de Ciências do Desporto e Educação Física da Universidade de Coimbra, com vista à obtenção do grau de Mestre em Treino Desportivo para Crianças e Jovens, na área Científica de Ciências do Desporto, na especialidade de Treino Desportivo.

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"If you're not making mistakes, then you're not doing anything. I'm positive that a doer makes mistakes."

(John Wooden)

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"O valor das coisas não está no tempo que elas duram, mas na intensidade com que acontecem. Por isso, existem momentos inesquecíveis, coisas inexplicáveis e pessoas incomparáveis."

(Fernando Pessoa)

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ABSTRACT

There are several studies describing anthropometric and physiological attributes of elite and young kayakers. However little is known about the equipment set-up associated with the athlete morphology. The aim of this study was to describe the anthropometric characteristics of athletes competing in the level of 15 and 16 years old and its relationship with paddle set-up and performance. Sample included 23 paddlers (15.39 ± 0.46 years) all performed 1000 meters. Physical fitness was assessed by performing a test of sit-ups, push-ups, pull-ups and handgrip strength. Anthropometric assessment included body mass, stature, sitting height, lengths (arm span, arm, forearm and hand), circumferences (brachial, brachial in maximum contraction and chest) and biacromial diameter. Body composition and upper limb volume in the dominant limb were also assessed. Paddle characteristics assessed were paddle length; blade length; blade width; hand grip distance; frontal blade area; angle between blades and the shaft diameter. Biological maturation was assessed by maturity offset and percentage of predicted mature stature. An association was found between better performances at 1000m and body mass ($rho \leq 0.05$), brachial circumference ($rho \leq 0.01$), brachial circumference in maximum contraction ($rho \leq 0.01$), chest circumference ($rho \leq 0.01$), upper limb volume ($rho \leq 0.05$), arm volume ($rho \leq 0.01$) and pull-ups ($rho \leq 0.01$). A predictive model it's possible to show that 48% of the paddle length is explained by the variation of sitting height, maturity offset or handgrip strength. Statistical differences between the 3 best times *vs.* 3 worst times performed was establish for training experience ($p \leq 0.05$); body mass ($p \leq 0.05$); brachial circumference ($p \leq 0.05$); brachial circumference in maximum contraction ($p \leq 0.05$); chest circumference ($p \leq 0.05$); arm length ($p \leq 0.05$); angle between blades ($p \leq 0.05$); pull-ups ($p \leq 0.05$) and time at 1000 meters ($p \leq 0.05$). This study offers the anthropometric profile of young male paddler, and reveals that athletes with slightly larger upper body dimensions and better results in pull-up test have better performance at 1000 meters; the regression equations provided could be used more objectively in the initial equipment set-up selection. This information may allow us to explore the feasibility of customizing the dimensions of the paddle, and be used as a guide in the process of talent identification.

Keywords: *flatwater; maturation; youth; anthropometry*

1. INTRODUCTION

Sport establishes itself as a central phenomenon in many societies (Gonçalves & Coelho-e-Silva, 2004) and proves to be a common feature in the lives of children and young people around the world (Coelho-e-Silva & Malina, 2004). Nowadays, research in sport has followed the path of some industries that proposes to help the Men, using as anchor the growing culture of the demand for excellence (Reid, Stewart & Thorne, 2004). The initiation of the organized sports practice has been observed in increasingly young ages (Anderson, 2005; Damore, Metzl, Ramundo & Pan, 2003), with various areas of study focusing on sports training, hopping that in the later stages of the youth sports training, it produces athletes who can achieve a high level of performance (Coelho-e-Silva, Figueiredo, Gonçalves & Ramos, 2002).

As sports become more competitive and specialized, detection, identification and selection of young talent, tends to occur in increasingly younger ages (Helsen, Starkes & Winckel, 2000). However there are no clarities that early involvement in sports training programs is a key to success years later. The training process should be continuous, well-targeted and well planned steps because, as stated in Balyi (2001), it takes 8-12 years of training, or 10,000 hours, so that an athlete can reach the elite level.

Naturally the detection process is influenced throughout the growth, being highly individual which results in a wide interindividual variability of the performance, especially during adolescence (Bunc, 2010). Coaches and researchers have been struggling in the attempt to adapt the anthropometric profile of athletes to the specific requirements of the sports, with the purpose of carry them to their maximum performance.

In canoeing, although there are studies which describe attributes, whether anthropometric or physiological of elite (Ackland et al., 2003; Nakamura, Borges, Sales, Serpeloni, & Kokubun, 2004; Michael, Rooney & Smith, 2008; Ridge, Broad, Kerr & Ackland, 2007; Van Someren & Howatson, 2008; Alves & Silva, 2009) and young kayakers (Aitken & Jenkins, 1998; Alacid et al., 2011*a*; Alacid et al., 2011*b*; Alacid et al., 2011*c*), few normative data exist in the scientific literature about the optimization of the equipment set-up according to the human morphology in sprint kayaking (Ong, Elliott, Ackland & Lyttle, 2006), seeming that an incorrect adjustment of the equipment will affect the comfort of the athlete, his ability to perform the technical movement in perfect conditions, and consequently his performance (Burke & Pruitt, 2003).

Consequently, athletes and coaches involved in kayak competitions are confronted with various equipment set-up decisions that affect performance. Often this process of tuning the equipment set-up requires hours of practice and depends on the subjective feedback of the athlete, driving the approach to a trial and error process. For many athletes, however, the equipment is defined more by comfort than any consideration of the mechanical advantage it may afford (Ong, Ackland, Hume, Ridge, Broad & Kerr 2005).

Therefore, the evidence presented above, appear to suggest that the adequate selection of the paddle set-up is vital to the success in this sport. So, how do coaches decide the optimal paddle set-up for their athletes (Ong et al., 2005), and what are the indicators on which they are based? Thus, is important to increase the knowledge about the youth kayaking, and equipment set-up, allowing coaches to select the equipment based on objective criteria.

The objective of this study is to examine the relationships established between the anthropometric characteristics of young kayakers, the paddle set-up, and the performance in sprint kayaking, allowing us to explore the feasibility of customizing the dimensions of the paddle and to design assessment batteries that allow the proper identification of young talent for canoeing, especially for kayak flatwater racing. Also, anthropometrically characterize the national kayaker's in the age group of 15 - 16 years of age. Being able to establish objective criteria will minimize the required hours of trial and error with the expectation of finding the ideal adjustment of the paddle for each athlete.

2. REVIEW

2.1.Sport equipment

Sports can be categorized by the energy systems predominantly used, or if the product of the effort involved is primarily determined by precision or strength. Another way to define the sport is the degree to which the equipment contributes to performance, there are sports where the equipment does not constitute almost any part in determining the result, e.g., judo; and sports in which equipment has a key role, e.g., motor sports (Miller, 2005). Olympic flatwater kayaking requires a high level of skill to succeed at the international level, and modifications in technique and equipment are made continuously to improve performance (Kendal & Sanders, 1992).

Does not seem necessary to investigate thoroughly to find evidence of technology in sports. Whether you are a casual runner with the latest model of sneakers for that purpose, the cyclist of the weekends that boasts a carbon fiber frame or even a renowned surfer who performs new moves on a board, the technology often has tremendous significance (Hunter, 2011). The developments of new materials and equipment designs have long been known to have an enormous impact on sports performance (Miller, 2006; Davis, 2007).

In canoeing, since the introduction of flatwater racing as a sport, many technological advances were introduced in either the design of the kayak or the paddle, both with the aim of improving the performance of the athletes (Michael, Smith, & Rooney, 2009). Although the improvements identified in performance cannot be attributed only to changes in equipment design, it was suggested that the change in the shape of the blade (flat to wing blade), has been the technological progress more successful in canoeing, leading to an improvement of the performances time (Robinson, Holt & Pelham, 2002).

It seems evident if we consult the time held by the winner in the 1000m race, in the Olympic Games of 1988 (approximately 3:55.0 min:sec) and the time held at the Olympic Games of 1992 (approximately 3:36.0 min:sec), this trend takes place clearly at the introduction of the wing blade design (Michael et al., 2009).

2.2.Kayak paddle

The flatwater is one of the most popular forms of competitive disciplines of kayaking, mainly in European countries and Australia. The performance criterion is the time required for paddling a designated distance. The average speed, with which the paddler is able to perform the course, will be determinant for the best performance (Michael, Rooney & Smith, 2008).

There are two ways of propelling a boat, with a single blade paddle, used on the canoe, or with a two blades paddle used to propel the kayak in which athletes are seated in the cockpit of the boat with legs partially extended outright (Michael, Smith & Rooney, 2009). According to the International Canoe Federation (2011), the paddles cannot, in any way, be fixed to the boat and there is no other regulations regarding the shape and size of the paddle and respective blades.

Despite the paddling technique, the introduction of the wing blade design is probably the most significant factor for determining the performance in kayaking, and consequently it will be reasonable to expect that the size and shape of the blade will also have an important role (Sumner, Sprigings, Bugg & Heseltine, 2003).

Since the drag force is directly proportional to the frontal area of the blade, the size of the blade used by the kayaker should correspond to their power generation capacity, in order to be efficient. If the size of the blade is larger or smaller than the optimum size, the energy expended by the paddler to keep their race pace is likely to increase (Sprigings, Mcnair, Mawston, Sumner & Boocock, 2006) and his ability to perform an efficient technique to decrease.

Sumner et al. (2003) tested three different blade' designs, and concluded that, as the coefficient of drag of the blades were practically the same independently of the shape of the blade, the choice of the size of the blade to increase the drag force may be based simply on the area and the paddling frequency without the need to take into account the design.

If we focus on the dimensions of the paddle in accordance with Zumerchik (1997), quoted by Ong et al., (2005) the right choice for the length of the shaft, the distance between handgrip and size of the blade, depends on the length, width and mass of kayak (this by itself depends on the discipline practiced), the stature and arm span of the kayaker.

For a given paddle length, the kayaker may alter the mechanical advantage of the propulsion system by simply changing the hand position in the shaft of the paddle (Ong et al., 2006). As a general rule, Rademaker (1977), quoted by Ong et al., (2005) suggests that the correct distance between handgrips is determined by keeping the shaft of the paddle above the head with the arms horizontal and forearms vertically forming a right angle with each other, dividing the paddle into three equal lengths.

However, this rule seems to be too general and empiric, seeming clear that the ideal "athletic type" has been suffering constant changes throughout the last century (Bemies, 1900; quoted by Norton & Olds, 2001) and is being radically replaced by different body types, highly specialized and increasingly diverging.

Sport imposes a specific morphology for obtaining success in individual sports and have their own set of physical characteristics required (Norton & Olds, 2001), but we must remember that the young athlete is not like the adult athlete, and for that reason the selection and set-up of the equipment, based on specific parameters of the sport and on age group, is a critical matter.

Have adequate equipment for a child is crucial to a positive learning experience on the sport, being erroneous to considerer the use of adult equipment set-up by young athletes, assuming that the equipment will fit as they grow. There are many sporting agents who underestimate the importance of getting the right equipment for the young from the very beginning (Hill, 2009).

2.3.Growth and maturation

The terms growth, maturation and development are commonly employed synonymously. Although they are interrelated, concepts that enclose have fundamental differences (Stratton, Relly, Williams & Richardson, 2004 and Baxter-Jones et al., 2005). From conception to physical maturation, growth is the dominant biological process in the first 20 years of life and involves not only changes in body size, but also in body proportion and composition.

The pubertal jump in growth coincides with a set of events from which I emphasize the peak growth velocity in height (PHV). The time (age) which the PHV occurs is also considered as an indicator of maturity (Malina, 2004a; Rowland, 2004; Stratton et al., 2004). The pubertal growth spurt in height in boys begins around age 12, reaches a peak growth rate at around age 14 and ends around age 18 (Figueiredo, 2007). However, (Philippaerts, Vaeyens, Janssens, Renterghem, Matthys, Craen, Bourgois, Vrijens, Beunen & Malina, 2006), warns that these considerations should be interpreted with reference of a large inter-individual variability.

Malina, Bouchard & Bar-Or (2004b) mention that the range of results reported in studies with the European population indicates the ages at PHV, between 13.8 and 14.2 years. Calculating the age of PHV in stature through the formula proposed by Mirwald, Baxter-Jones, Bailey & Beunen (2002), has demonstrated to estimate the maturity state within a margin of error of 1.18 years, 95% of the time in boys.

Foreseeing new formulas for determining the mature height without using the skeletal age, Khamis & Roche (1994), used predictor variables where the coefficients for the calculation of mature height are age-specific. This method was developed with a sample of the Fels Longitudinal Study and the authors found an average error in boys, around 2.2 cm height between the predicted and actual height at age 18. This error shows only a slight increase compared to that seen in the method using skeletal age. The coefficients for the calculation of this method were published again in an erratum by Khamis & Roche (1995).

The maturity offset is an indicator of temporal distribution proposed by Mirwald et al., (2002), which uses chronological age, body mass, height, sitting height and leg length. Being the age at PHV considered the main event of somatic maturation and one of the most used indicators in longitudinal studies, according to Malina et al., (2004b), this method proposes to estimate the distance in years, which the subject is of PHV for height, this value can be negative (if the subject has not yet reached the PHV) or positive (if already has exceeded the PHV).

For this reasons it's essential that all prospective studies in children, both in context of youth sport and research investigations, attempt to control for maturity (Baxter-Jones, et al., 2005).

There are several questions regarding the trainability of young athletes, while the answer to these questions remains inconclusive. Concerning the strength, it is known that the manifestation of this ability suffers increases during childhood and adolescence, whose variations are attributable to gains in muscle mass, and the development of the neuroendocrine and neuromuscular systems (Matos & Winsley, 2007).

For the same authors, both the prepubertal child and the adolescent can demonstrate significant gains in muscle strength (13-30%) with resistance training. Muscular hypertrophy is limited in prepubertal children but more often observed from puberty onwards, and may reflect changes in the concentrations of growth and sex hormones. Regardless the changes in muscle hypertrophy, neuromuscular adaptations support the increments of strength in the young.

2.4.Anthropometry in canoeing

The anthropometric characteristics of athletes are, in most cases, very different, given the specific requirements of each sport and many of these features are caused by heredity and training, among other factors that can contribute greatly to the success. Thus, many researchers have tried to investigate, particularly over the last two or three decades, the physical characteristics of elite athletes in the attempt to explain athletic performance, linking it with success and failure in sport (Gobbo, Papst, Carvalho, Souza, Cuattrin & Cyrino, 2002).

There are few studies that describe the anthropometric characteristics of young kayakers and those existing mainly focus on the ages of 13 to 14 years (Aitken & Jenkins, 1998; Alacid, López-Miñarro, Martínez & Ferrer-López, 2011*a*; Alacid, Marfell-Jones, López-Miñarro, Martínez & Muyor, 2011*b*).

Most of the studies that focus part or the entire of his research on kayakers' anthropometry, whether in young or in adults, have been looking at the characteristics commonly associated with success in this sport, ie, body mass, stature, sitting height, arm span, percentage of body fat, circumference of the upper limb (arm, forearm, relaxed and at maximum contraction), circumference of the chest; biacromial diameter, bi-iliocristal diameter; length of the upper and lower limbs, (Aitken & Jenkins, 1998; Gobbo et al., 2002; van Someren & Palmer, 2003; Ackland, Ong, Kerr & Ridge, 2003; van Someren & Howatson, 2008; Akca & Muniroglu, 2008; Alacid et al., 2011*b*;Alacid, Muyor & López-Miñarro, 2011c).

Alacid et al. (2011c) in is study, referred that the characteristics in terms of proportionality of kayakers of the 15-16 age group, compared with the elite paddlers showed an overall structure with many similarities. The main differences from the elite paddlers focused on clearly lower proportions, lower contracted arm circumferences, chest girth and lower biacromial diameter.

To our knowledge, the studies that focus on understanding the relationship between the anthropometric characteristics of the kayakers and their paddle set-up were performed with adults (Ong et al., 2005; Ong et al., 2006; Diafas, Kaloupsis, Dimakopoulou, Zelioti, Diamanti & Alexiou, 2012).

These studies demonstrated that the selection of the paddles' length, the distance between the hand grips and the dimensions of the blade are influenced by the stature and the dimensions of the upper limbs. The distance between the hand grips for example, can be predicted using the chest breadth, stature and the arm span (Ong et al, 2005). Ong et al., (2006) reported that only the distance between the hand grips had significant associations with anthropometric parameters, and Diafas et al., (2012) stated that total arm length, the arm span and the stature were significantly correlated with de paddle length.

2.5.Body Composition

Body composition is the proportion between the various body components and total body mass, and is usually expressed by the percentages of fat and lean mass. The body composition assessment is divided into three groups: direct evaluation, indirect evaluation and double indirect evaluation (Monteiro & Filho, 2002), being this last one the less accurate and which includes anthropometry.

From a bicompartmental perspective, there is stabilization or a slight increase in fat mass in males during the pubertal spurt. However, there is a sharp increase of fat-free body mass during this period, as a result of the substantial increase in muscle and bone mass (Malina et al., 2004b).

The equations of Slaughter, Lohman, Boileau, Horswill, Stillman, Loan & Bemen, (1988) are the most widely used in studies of body composition in pediatric populations, this author used three methods to predict the percentage of body fat with specific groups of children and youngsters, Caucasian and Black, using different assessment techniques based on a three compartment model and with crossed validity and anthropometric measurements based on the sum of two skinfolds, triceps with subscapular and triceps with germinal taking into account different constant per each pubertal status.

These equations are based on an empirically derived multicomponent method utilizing measurement of body density, total body water, and bone mineral content of radius and ulna. The sample used to derive these particular equations consisted of 50 boys (mean age 9-8 years) from USA (Reilly, Wilson & Durnin, 1995) and were validated in a study by Janz, Nielsen, Cassady, Cook, Wu & Hansen (1993).

The study proceeded to cross validation by comparing the measured criterion of the equations of Slaughter et al. (1988) performed with a two-compartment model using hydrostatic weighing. Using a sample of 122 subjects aged between 8 and 17 years, it showed values validation with high correlations of r = 0.79 - 0.99 and standard error of estimate between 3.6 and 4.6%.

2.6.Physical fitness assessment

The measurement of physical fitness in children and youth has long been a topic of interest to physical educators, to exercise and health scientists, and lately to private organizations dealing with sport, fitness, and health. Numerous fitness tests have been constructed by physical educators, exercise physiologists, sport physicians, and sport trainers during the last 100 years (Kemper & Mechelen, 1996).

Physical fitness is the capacity to perform physical activity, and makes reference to a full range of physiological and psychological qualities. Physical activity is any body movement produced by muscle action that increases energy expenditure, whereas physical exercise refers to planned, structured, systematic and purposeful physical activity (Ortega, Ruiz, Castillo & Sjöström, 2008).

For the same author this characteristic is in part genetically determined, but it can also be greatly influenced by environmental factors. Physical exercise is one of the main determinants. Childhood and adolescence are crucial periods of life, since dramatic physiological and psychological changes take place at these ages (Ortega et al., 2008).

Furthermore the use of resistance training (RT) by children and adolescents has attracted increased interest as a means to improve health- and performance-related fitness components. The National Strength and Conditioning Association (NSCA) defines RT as a specialized form of conditioning involving the progressive use of a wide range of resistive loads and a variety of training modalities designed to enhance health, fitness, and sports performance. Numerous reviews and position papers published by advisory bodies have dispelled previous concerns regarding the safety and efficacy of RT for children and adolescents. (Faigenbaum, Kraemer, Blimkie, Jeffreys, Micheli, Nitka & Rowland 2009).

Resistance training in children and adolescents is reported to have beneficial effects on: (1) muscular strength and power; (2) prevention and rehabilitation of injuries; (3) long term health; (4) cardiovascular fitness; (5) body composition; (6) bone mineral density; (7) blood lipid profiles; (6) self-esteem and (7) mental health (Faigenbaum et al., 2009).

Also the NSCA reports strength gains of approximately 30% are typically observed after appropriately designed and supervised short-term RT programs undertaken by children and adolescents, RT may also benefit sports performance. It has been theorized that increases in the muscular strength and power levels of adolescents after participation in RT may improve sporting performance (Faigenbaum et al., 2009). Despite considerable heterogeneity in terms of study design and types of training, there is sufficient evidence to conclude that RT interventions have the potential to improve muscular power in adolescent athletes (Harries, Lubans & Callister, 2012).

Besides that, flatwater kayaking is a predominantly upper body sport in which the trunk rotates from a seated base of support and involves concurrent trunk rotation and stabilization (Mann & Kearnaey, 1980; quoted by McKean & Burkett, 2010). Paddlers require significant strength of the upper body (Akca & Muniroglu, 2008) as well as the trunk and core (Fry & Morton, 1991; quoted by McKean & Burkett, 2010). Thus, the earlier evidence has led to the choice of the assessment battery employed in the present work.

3. METHODOLOGY

3.1.Sample

This study involved 23 young Portuguese male kayakers (15.39 ± 0.46 years), 6 of which have integrated the Juveniles national team. All the evaluated athletes compete nationally, and are enrolled in various teams. These athletes participated in the national control of 1000 and 2000 meters organized by the Portuguese Canoe Federation (FPC). This event was held under difficult weather conditions, with long periods of showers during most of the race, and against wind. It was possible to record data relating to air temperature and the wind speed (table 1), which according to the Beaufort scale for wind speed (Mather, 1969), ranged between light air (1.1-5.5 km / h) and moderate breeze (20.0-28.0 km / h).

Table 1. Weather conditions recorded during the race.

Variables	Units	Min	Max	Mean	Std. Deviation
Wind speed	km/h	4.3	27.1	13.4	7.9
Air temperature	ºC	16.4	16.8	16.6	0.2

Data collection took place two weeks after the competion organized by the FPC at the *Centro de Alto Rendimento de Montemor-o-Velho*. Essentially it was collected information regarding the anthropometric measurements, the paddle set-up, the physical fitness and some information concerning the sport participation of the athletes. For these purpose a group of experts was attending the athletes, and were divided into groups of two observers, one for the anthropometric and equipment data and other for the physical fitness assessment. Tests were also performed in the morning at the same hour interval (9:30 – 11:00).

3.2.Anthropometry

It is known that the existence of universal batteries applicable to all studies is a utopic issue. Anthropometry allow quantification of the external dimensions of the human body, by a set of standardized technical measures, and standard positions for measure the subject, and resource to the use of appropriate instruments (Claessens, Beunen &

Malina, 2000). This also involves the use of carefully defined body points for the measurements, a special positioning of the subject during the measurements and the use of appropriate instruments. Measurements are normally divided into body mass (weight), distances between points or lines which can be lengths, diameters and circumferences; surfaces, volume and mass measurements, there are also folds of subcutaneous adiposity (Lohman *et al*., 1988), having as major advantage of their non-invasive nature and the easy transportation and use of the equipment that are usually portable. Thus, becomes indispensable the use of instruments that are suitable and in good condition.

In our study we adopted, the procedures described by Lohman et al. (1988), for body mass, stature, sitting height, lengths (arm span, arm, forearm and hand), circumferences (brachial, brachial in maximum contraction and chest), diameters (biacromial) and skinfolds (triceps and subscapular).

For body mass we decided to restrict the clothing to light items, being the observed in shorts and barefoot, using a SECA balance (model 770, Hanover, MD, USA) which provides data to the nearest 0.1 kg.

Stature was measured with the same clothing allowed for the measurement of body mass; the observed was docked to a wall, with the head adjusted by the observer in order to correctly orient the Frankfurt Horizontal Plane. Finally, following the recommendations by Gordon et al. (1988), the subject will be asked to inhale as much air volume while maintaining an upright position. For sitting height the observed were seated on a bench to enable the measurement of the sitting height. Arm span was obtained at shoulder height and is the distance between each *dactylion*, ie between each distal end of middle fingers, being the observed with the chest against a wall and with their arms abducted 90°, and perfectly aligned. These three variables were measured to the nearest 0.1 cm using a metallic tape.

The arm (length between the point *acromiale* and the upper edge point *radiale)* the forearm (length between the *radiale* and the *stylion* points) and the hand (length of the hand is measured between the *stylion*, or the flexion fold of the wrist, and the distal point of the middle finger) was measured to the nearest 0.1 cm using a sliding caliper (Rosscraft Campbell Caliper 20).

For the biacromial diameter the subject was measured in a standing position, in the anthropometric reference position, with the upper limbs lying to side of the trunk. The upper and posterior trunk is devoid of any clothing, allowing the identification of the acromial points using a sliding caliper (Rosscraft Campbell Caliper 20) which provides data to the nearest 0.1 cm.

The circumference of the chest (measured at the fourth costosternal joint, and laterally corresponds to the level of the sixth rib in the horizontal plane and at the end of a normal expiration), brachial (measured with the member relaxed, at the midpoint of the length of the arm) and brachial in maximum contraction (measured with the right arm flexed with a right angle on the elbow joint. A measuring tape involves the greatest circumference of the arm in maximal contraction) were measured to the nearest 0.1 cm using an anthropometric tape (Rosscraft).

Skinfolds were measured using the thumb and forefinger, firmly highlighting the skin and subcutaneous fat and of the other tissues underlying and placing the tips of caliper 2 cm beside the fingers, to a depth of 1 cm and using a Slim Guide Skinfold Caliper which provide data to the nearest 1.0 mm. The percentage of body fat was derived from the equation of Slaughter et al. (1988), it is empirically based on a multicompartmental method, using the measurement of body density, the amount of total body water, and bone mineral content of the radius and ulna.

It was used the formula for the % fat mass for children with triceps and subscapular folds <35 mm:

Boys = 1.21 (triceps + subscapular) - 0.008 (triceps + subscapular) ^{2} - 1.7

The upper limb volume was assessed in the dominant limb. For measuring upper limb circumferences and lengths, six levels were pen-marked in the upper limb: the ulnar styloid, the largest girth of the forearm, the olecranon, the largest girth of the arm, the distal insertion of the deltoid and the acromion (Figure 1).

The six circumferences were measured passing the tape around the upper limb at each marked level and the five lengths were measured between two successive marks. Five truncated cones were thus defined: from the wrist (ulnar *styloid*) to the largest girth of the forearm (V_1), from this last girth to the olecranon (V_2), from the olecranon to the largest girth of the arm (V_3), from this last girth to the girth at the distal insertion of the deltoid (V_4), and from this last girth to the proximal insertion of the deltoid (V_5) (Sander, Hajer, Hemenway & Miller, 2002; Karges, Mark, Stikeleather & Worrell, 2003; Rogowski, Ducher, Brosseau & Hautier, 2008).

The volume of the 5 cones in the dominant upper limb was calculated using the truncated cone equation (Jones & Pearson, 1969; Sander et al., 2002; Karges et al., 2003; Rogowski et al., 2008). The forearm volume V_b was calculated by the sum of the two truncated cones between the wrist and the elbow ($V_1 + V_2$). The arm volume V_a was calculated by the sum of the three truncated cones between the elbow and the proximal insertion of the deltoid ($V_3 + V_4 + V_5$). The same anthropometrist made all of the anthropometric measurements.

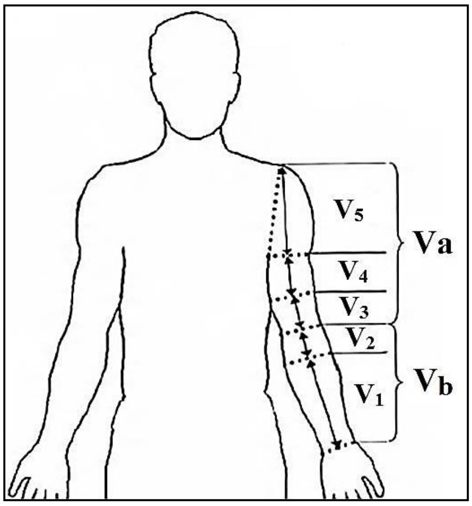

Figure 1. Calculation of the upper limb volume. Dotted lines portray the spots used to measure the girths of the upper limb. Arrows show each length between two lines of circumference measurements. V_1, V_2, V_3, V_4 and V_5 match to the five truncated cones used to determine the upper limb volume. V_b corresponds to the forearm volume and V_a correspond to the arm volume. (Adapted from Rogowski et al., 2008).

All the study' variables were subjected to a process of intra-observer concordance, i.e. the specialist involved in the anthropometric measurements was targeted by determining technical error of measurement. Technical errors of measurement (Perini, Oliveira, Ornellas & Oliveira, 2005) for anthropometric measures ranged from 0.1% to 2% and reliability ranged from 97.1% to 100%.

3.3.Paddle set-up

The set-up of equipment for athletes was measured by the same investigator. The characteristics assessed were: the paddle length (horizontal distance between the tips of the blades); blade length (horizontal distance between the tip of the blade and the point of the shaft where the structure begins to form the blade); blade width (maximum width of the blade); hand grip distance (horizontal distance between the joints of the third digit with the athlete using the usual grip); frontal blade area (will be the quantity that expresses the extent of the paddle plane surface); angle between blades (angle between the two blades that form a paddle); diameter of the shaft (the diameter of the shaft will be the straight line segment that passes through the center of the shaft and whose endpoints are on the boundary of shaft).

The paddle length was measured to the nearest 0.1 cm using a metallic tape, the blade length; the blade width and the hand grip distance were measured to the nearest 0.1 cm using a sliding caliper (Rosscraft Campbell Caliper 20); the diameter of the shaft was measured to the nearest 0.1 mm using a sliding caliper (Starrein Caliper); angle between blades was measured using a special device with a goniometer that measured to the nearest 0.1º; the frontal blade area were determined with the assistance of SolidWorks Premium® 2013, using the area function on the 2-D digital images taken of the different blades.

3.4.Physical fitness assessment

The physical fitness of the athletes was assessed by performing a test of sit-ups, push-ups, pull-ups and handgrip strength. Once, several physical fitness test batteries, e.g. the Eurofit test battery, the American College of Sports Medicine's (ACSM) guidelines for exercising and the Canadian Physical Activity, Fitness & Lifestyle Approach Protocol (CPAFLA) have been developed and used globally through the years.

However protocols in some tests in the above mentioned physical fitness test batteries are different from each other, making comparisons difficult (Augustsson, Bersås, Thomas, Sahlberg, Augustsson & Svantesson, 2009). We decide to use the standard protocol of the Fitnessgram test battery (Fitnessgram, 1999) for the push-up, the sit-up and pull-up tests, and the standard protocol of Eurofit (1988) for the handgrip strength test. The choice of this formality coincides with the fact that the Fitnessgram test battery is an integral part of the curriculum of Physical Education in Portugal, and thus the subjects to assess are familiarized with the test protocols, and for enable comparison with data from other studies.

Prior to the assessment of physical fitness, a warm-up was performed during 5 minutes. This warm-up consisted in conducting exercises of general and specific activation. For the overall activation was performed a 2 minutes articular warm-up followed by 20 squats. In the specific activation the subjects was requested to do 20 push-ups against a wall, and to complete the warm-up session was requested to execute 4 roll out planks. After the warm-up and during the physical assessment the resting period between exercises was 90 seconds. During the assessments was respected the same sequence of test application (pull-ups, push-ups, sit-ups and handgrip strength).

3.4.1. Pull-up test

Complete, correctly, as many possible elevations. The subject assumes the starting position, hanging on the bar with the arms fully extended with the palms facing outwards, and the lower limbs in extension and without touching the ground. The subject should use the arms to lift the body until the chin is above the bar, lowering the body back to the starting position.

3.4.2. Push-up test

The athlete must complete as many push-ups as possible, at a rate of 20 push-ups per minute or 1 push-up every 3 seconds. The athlete must place itself in plank position with both feet together and the body aligned and while performing the flexion must bend the elbow approximately 90 degrees, in order to keep the arm parallel to the floor.

3.4.3. Sit-up test

The athlete must complete as many repetitions as possible up to a maximum of 75 at a rate of 20 per minute or 1 repetition every 3 seconds. Lying on a mattress in a supine position with the knees flexed at an angle of 140 º and with the sole of the foot in contact with the floor and with the lower limbs slightly apart. The upper limbs are straight and parallel to the torso with the palms resting on the mat. The head should be in contact with the mat and the heels on the floor, the subject initiates the movement by sliding his fingers until he reach the far side of the measuring strip.

3.4.4. Handgrip strength test

The performer takes the dynamometer (Hand Dynamometer - Lafayette model 78010 made in USA), with the preferred hand, adjusting the measure of distance between the rods, according to the size of the hand. The test consists in performing the maximum power by pressure of the fingers against the rods. Without any body contact, the dynamometer should be in the extension of the extended arm.

3.5.Somatic maturation

There are different somatic and noninvasive indicators that enable the understanding of tempo and timing of the biological processes that occur toward the mature state. In order to predict the mature stature of young athletes, it was used the procedure proposed by (Khamis & Roche, 1994, 1995).

This method of noninvasive estimation of maturational status, dispenses bone age to calculate the predicted mature height, created by the same author (1993), and provides for the use of current stature, body mass and mean parental stature. Then we use the multiplication of variables presented by the weighting coefficients associated with the chronological age of the subjects:

Predicted mature stature = intercept + stature × (*coefficient for stature*) + body mass × (*coefficient for body mass*) × mean parental stature × (*coefficient for the mean parental stature*)

The coefficients of the Khamis-Roche method are shown in inches and pounds, and require its conversion to conventional metric system (centimeters and kilograms). The maturational indicator is given by the percentage of predicted mature stature already achieved at the time of measurement. This method assumes that an individual who is close to its mature stature is advanced while an individual who is below the predicted mature stature for his age is delayed (Cumming, Standage, Gillison, Dompier, & Malina, 2009):

% Predicted mature stature = (height at the moment / predicted mature stature) × 100

To determine the maturity offset it was used the formula proposed by Mirwald et al. (2002). For this purpose it is necessary to collect the following information: chronological age (*CA*), stature (*s*), body weight (*w*), (*wt / h*) x 100 (*ratio wt/h*), length of the lower limb (*LL length*), and sitting height (*sh*):

Maturity offset = -9,236 + [0,0002708 × (*LL length* × *sh*)] + [(-0,001663 × (*CA* × *LL length*)] + [(0,007216 × (*CA* × *sh*)] + (0,02292 × *ratio wt/h*)

The result of this equation estimates the distance in years, that the subject is of the peak growth velocity for height (PHV), the value can be negative (if not yet reached the PHV) or positive (now surpassed PHV).

3.6.National control of 1000 and 2000 meters

The control was held in the time trial format (Figure 2), the 2000 meters trial was the first to be conducted followed by the 1000 meters, all athletes were entitled to an interval of 15 minutes between the first and second trial.

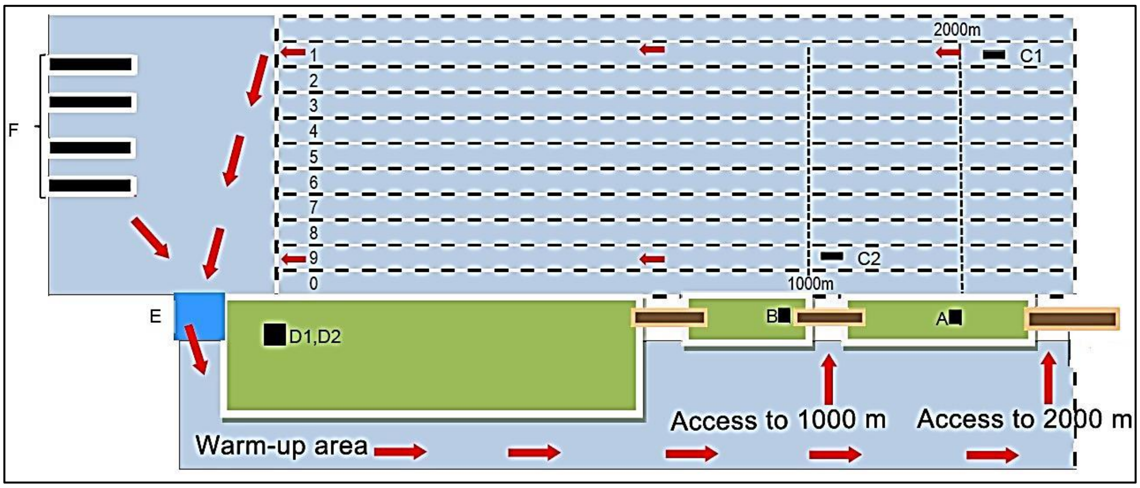

Figure 2. Layout of the race venue (Adapted from *Controlo Nacional de Velocidade – Caderno de Prova*).

3.7.Weather conditions

The weather conditions were measured using a digital anemometer / thermometer (TFA 42.6000.06 HiTrax, Germany). The accuracy of measurement of the wind speed was ±5% and the air temperature measured up to the nearest 0.1 °C.

3.8.Statistical Analysis

Statistical analysis includes calculating descriptive statistics for the total sample (minimum, maximum, mean and standard deviation) and Shapiro-Wilk test was performed to check normality. Afterwards we proceed with the finding of relationships between the anthropometric characteristics of young kayakers the paddle set-up and the performance. This relationship was tested with the assistance of a linear regression analysis. The Spearman correlation coefficient was calculated in order to ascertain the strength of the correlations between the variables and thereby facilitate the selection of independent variables as input data for regression analysis, and the Mann-Whitney test to assess the difference between the best and the worst times. Significance was set at $p < 0.05$. The Statistical Program for Social Sciences – SPSS, version 20.0 for Windows was used.

4. RESULTS

Descriptive statistics and the Shapiro-Wilk test of adjustment to normal distribution for the total sample are summarized in table 2.

Table 2. Descriptive statistic and the Shapiro-Wilk test for total sample (n=23).

Variables	Units	Min	Max	Mean	Std. Deviation	Shapiro-Wilk (*SW*)	
						value	*p*
Training	years	.3	9.0	3.4	2.2	0.948	0.262
Hours per week	hours	6.0	20.0	11.3	3.6	0.901	0.026
Chronological age	years	14.20	16.00	15.39	0.46	0.896	0.021
Estimated mature stature	cm	170.9	194.7	180.1	6.4	0.947	0.249
Estimated mature stature	%	90.2	99.3	96.0	2.3	0.952	0.326
Maturity offset	years	.9	2.8	1.7	0.5	0.972	0.745
Stature	cm	163.9	189.9	172.8	6.4	0.945	0.232
Sitting height	cm	85.1	97.1	91.6	2.8	0.985	0.968
Body mass	kg	49.6	78.0	63.6	7.1	0.977	0.847
Fat mass	%	8.5	21.0	15.1	3.4	0.970	0.685
Arm span	cm	166.8	193.2	177.7	7.5	0.938	0.165
Arm	cm	30.2	37.9	34.1	1.9	0.962	0.498
Forearm	cm	25.8	30.6	28.5	1.2	0.980	0.900
Hand	cm	17.7	20.2	18.6	0.7	0.887	0.014
Brachial	cm	22.8	31.0	27.2	1.8	0.987	0.986
Brachial maximum contraction	cm	25.7	34.2	30.6	2.1	0.961	0.474
Chest	cm	83.7	103.8	92.3	5.0	0.975	0.812
Biacromial	cm	35.2	41.7	38.6	1.9	0.956	0.379
Upper limb volume	L	2508.3	4514.7	3327.8	436.4	0.960	0.473
Arm volume	L	1664.7	3026.2	2184.8	315.5	0.957	0.401
Forearm volume	L	843.7	1488.5	1143.0	133.5	0.955	0.368
Paddle length	cm	204.3	216.6	212.2	2.8	0.930	0.112
Blade length	cm	44.6	49.6	48.3	1.2	0.756	0.000
Blade width	cm	14.6	16.7	15.8	0.5	0.918	0.061
Handgrip distance	cm	62.9	79.4	70.1	4.2	0.961	0.492
Frontal blade area	cm^2	573	711	650.8	34.1	0.949	0.285
Angle between blades	gr°	43.1	74.2	60.7	8.9	0.955	0.375
Shaft diameter	mm	26	31	28.8	1.5	0.817	0.001
Push-ups	reps	11	50	34.1	11.7	0.903	0.030
Pull-ups	reps	1	21	9.8	6.1	0.933	0.124
Sit-ups	reps	20	75	67.6	16.9	0.494	0.000
Handgrip strength	kg/f	31	61	44.1	6.7	0.949	0.277
1000 meters	min:s	4:18	6:23	5:34	0.6	0.910	0.042
2000 meters	min:s	9:07	12:57	10:08	0.9	0.886	0.013
Combined time	min:s	13:26	19:21	15:21	1.5	0.936	0.149

As presented in table 2, chronological age (*SW* value = 0.896, p = 0.021), hand length (*SW* value = 0.887, p = 0.014), hours of training (*SW* value = 0.901, p = 0.026), push-ups (*SW* value = 0.903, p = 0.030), blade length (*SW* value = 0.756, p = 0.000), shaft diameter (*SW* value = 0.817, p = 0.001), sit-ups (*SW* value = 0.494, p = 0.000) the time at 1000 meters (*SW* value = 0.910, p = 0.042) and the time at 2000 meters (*SW* value = 0.886, p = 0.013) did not fit the normal distribution.

Relatively to the correlations between chronological age; years of practice; stature; sitting height; body mass; body composition (% fat mass); arm span; arm length; hand length; brachial circumference; brachial circumference in maximal contraction; chest circumference; biacromial diameter; upper limb volume; arm volume; forearm volume and the paddle length; blade length; blade width; angle between blades; handgrip distance; frontal blade area; shaft diameter; it is possible to observe (table 3) that the chronological age correlates significantly and negatively with the blade length (*rho*≤0.05), the blade width (*rho*≤0.05) and the frontal area of the blade (*rho*≤0.01); the years of practice correlates significantly and positively with the handgrip distance (*rho*≤0.01); the maturity offset correlates significantly and positively with the paddle length (*rho*≤0.01); the sitting height correlates significantly and positively with the paddle length (*rho*≤0.05); the body mass correlates significantly and positively with the blade width (*rho*≤0.05).

Regarding the correlations between chronological age; years of practice; stature; sitting height; body mass; body composition (% fat mass); arm span; arm length; hand length; brachial circumference; brachial circumference in maximal contraction; chest circumference; biacromial diameter; upper limb volume; arm volume; forearm volume and the push-ups; pull-ups; sit-ups; handgrip strength; time at 1000 m; time at 2000 m and the combined time (table 4); it is possible to observe that the years of practice correlates significantly and negatively with the time at 1000 m (*rho*≤0.01), the time at 2000 m (*rho*≤0.05), the combined time (*rho*≤0.01) and correlates significantly and positively with the pull-ups (*rho*≤0.05); the maturity offset, the sitting height and the body mass correlates significantly and positively with the handgrip strength (*rho*≤0.01);

body mass also correlates significantly and negatively with the time at 1000 meters (*rho*≤0.05); the % fat mass correlates significantly and negatively with the push-ups (*rho*≤0.05); the arm length correlates significantly and positively with the push-ups (*rho*≤0.05) and the brachial circumference and the brachial circumference in maximum contraction correlates significantly and negatively with the time at 1000 m (*rho*≤0.01); the time at 2000 m (*rho*≤0.05) and the combined time (*rho*≤0.01) and also correlates significantly and positively with the pull-ups (*rho*≤0.01) and the handgrip strength (*rho*≤0.01); the chest circumference correlates significantly and negatively with the time at 1000 m (*rho*≤0.01); the time at 2000 m (*rho*≤0.05) and the combined time (*rho*≤0.01) and correlates significantly and positively with the pull-ups (*rho*≤0.05) and the handgrip strength (*rho*≤0.01).

The biacromial diameter and the forearm volume correlates significantly and positively with the handgrip strength (*rho*≤0.01); the upper limb volume correlates significantly and negatively with the time at 1000 m (*rho*≤0.05) and the combined time (*rho*≤0.05) and correlates significantly and positively with the handgrip strength (*rho*≤0.01) and the arm volume correlates significantly and negatively with the time at 1000 m (*rho*≤0.01); and the combined time (*rho*≤0.01) and also correlates significantly and positively with the handgrip strength (*rho*≤0.01).

Table 3. Correlations between chronological age; years of practice; stature; sitting height; body mass; % of fat mass; arm span; arm length; forearm length; hand length; brachial circumference; brachial circumference in maximal contraction; chest circumference; biacromial diameter; upper limb volume; arm volume; forearm volume and the paddle length; blade length; blade width; angle between blades; handgrip distance; frontal blade area; shaft diameter.

		CA	**Years practice**	**MO**	**Stature**	**Sitting height**	**Body mass**	**%Fat mass**	**Arm span**	**Arm length**	**Forearm length**	**Hand length**	**Brachial C.**	**Br.C.MC**	**Chest C.**	**Biac.D.**	**ULV**	**Arm volume**	**FA.V.**
Paddle length	*rho*	0.204	-0.138	0.592**	0.244	0.500*	0.362	0.187	-0.014	0.189	-0.150	0.044	0.187	0.217	0.191	-0.022	0.221	0.273	0.174
	Sig.	0.350	0.531	0.003	0.262	0.015	0.090	0.394	0.950	0.388	0.495	0.842	0.394	0.321	0.382	0.920	0.311	0.208	0.427
Blade length	*rho*	-0.524*	0.095	-0.180	-0.205	-0.088	0.106	0.341	-0.205	-0.050	-0.241	-0.139	0.341	0.307	0.244	0.133	0.175	0.245	0.121
	Sig.	0.010	0.667	0.411	0.348	0.688	0.630	0.111	0.349	0.820	0.268	0.526	0.111	0.154	0.261	0.544	0.424	0.260	0.583
Blade width	*rho*	-0.497*	0.054	0.055	0.013	0.301	0.428*	0.329	-0.029	-0.099	-0.258	-0.024	0.329	0.301	0.348	0.372	0.316	0.273	0.361
	Sig.	0.016	0.806	0.804	0.953	0.163	0.042	0.125	0.896	0.654	0.235	0.913	0.125	0.163	0.104	0.081	0.142	0.207	0.091
Angle b.blades	*rho*	-0.164	-0.003	-0.127	-0.101	-0.151	-0.198	0.047	-0.063	-0.112	0.053	-0.122	0.047	-0.003	-0.050	0.242	-0.121	-0.053	-0.095
	Sig.	0.454	0.988	0.563	0.647	0.492	0.364	0.832	0.775	0.609	0.812	0.578	0.832	0.990	0.822	0.266	0.584	0.811	0.667
Handgrip distance	*rho*	0.284	0.539**	0.221	0.143	0.066	0.201	0.274	0.279	0.390	0.212	0.045	0.274	0.316	0.250	0.113	0.263	0.233	0.218
	Sig.	0.188	0.008	0.310	0.514	0.766	0.359	0.205	0.197	0.066	0.332	0.838	0.205	0.142	0.251	0.607	0.226	0.284	0.317
Frontal blade area	*rho*	-0.553**	0.079	-0.135	-0.196	0.068	0.156	0.331	0.279	-0.143	-0.272	-0.297	0.331	0.281	0.214	0.121	0.208	0.248	0.140
	Sig.	0.006	0.719	0.539	0.371	0.759	0.477	0.123	0.197	0.514	0.209	0.169	0.123	0.193	0.327	0.582	0.340	0.254	0.523
Shaft diameter	*rho*	0.283	0.010	0.040	0.190	-0.013	-0.129	-0.246	0.119	0.400	0.070	0.020	-0.246	-0.232	-0.288	-0.212	-0.164	-0.247	-0.024
	Sig.	0.191	0.964	0.855	0.386	0.951	0.556	0.258	0.590	0.058	0.751	0.929	0.258	0.288	0.182	0.330	0.455	0.256	0.914

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

». Chronological Age (CA); Maturity offset (MO); Brachial circumference (Brachial C.) Brachial circumference in maximum contraction (Br.C.MC); Biacromial diameter (Biac. D); Upper limb volume (ULV); ForearmVolume (FA.V.); Handgrip Strength (HGS); Angle between blades (Angle b.blades); Chest circumference (Chest C.)

Table 4. Correlations between chronological age; years of practice; stature; sitting height; body mass; % of fat mass; arm span; arm length; forearm length hand length; brachial circumference; brachial circumference in maximal contraction; chest circumference; biacromial diameter; upper limb volume; arm volume; forearm volume and the push-ups; pull-ups; sit-ups; handgrip strength; time at 1000 m; time at 2000 m and the combined time.

		CA	**Years practice**	**MO**	**Stature**	**Sitting height**	**Body mass**	**%Fat mass**	**Arm span**	**Arm length**	**Forearm length**	**Hand length**	**Brachial C.**	**Br.C.MC**	**Chest C.**	**Biac.D.**	**ULV**	**Arm volume**	**FA.V.**
Push-ups	*rho*	0.012	-0.025	-0.036	-0.280	-0.112	-0.209	-0.451*	-0.336	-0.169	-0.356	-0.206	0.121	0.075	0.099	-0.083	-0.236	-0.118	-0.337
	Sig.	0.956	0.911	0.872	0.195	0.609	0.338	0.031	0.117	0.440	0.095	0.345	0.581	0.733	0.652	0.706	0.278	0.591	0.116
Pull-ups	*rho*	-0.199	0.479*	0.165	0.075	0.187	0.198	-0.158	0.092	0.285	-0.071	0.012	0.549**	0.589**	0.420*	0.248	0.333	0.401	0.289
	Sig.	0.363	0.021	0.451	0.734	0.393	0.366	0.472	0.676	0.188	0.746	0.956	0.007	0.003	0.046	0.253	0.121	0.058	0.181
Sit-ups	*rho*	0.223	0.078	0.131	0.242	0.123	-0.168	-0.274	0.159	0.459*	0.081	0.102	-0.287	-0.263	-0.327	-0.277	-0.263	-0.295	-0.144
	Sig.	0.306	0.722	0.553	0.265	0.577	0.445	0.206	0.470	0.027	0.714	0.643	0.184	0.226	0.128	0.200	0.225	0.172	0.514
Handgrip strength	*rho*	0.084	0.059	0.714**	0.292	0.660**	0.695**	0.163	0.278	0.036	0.126	0.260	0.556**	0.723**	0.720**	0.536**	0.694**	0.670**	0.647**
	Sig.	0.702	0.788	0.000	0.177	0.001	0.000	0.457	0.199	0.876	0.566	0.231	0.006	0.000	0.000	0.008	0.000	0.000	0.001
1000 m	*rho*	0.186	-0.643**	-0.255	-0.052	-0.274	-0.413*	0.078	-0.168	-0.330	0.071	-0.258	-0.631**	-0.653**	-0.541**	-0.279	-0.463*	-0.527**	-0.352
	Sig.	0.395	0.001	0.239	0.812	0.205	0.050	0.723	0.445	0.124	0.748	0.235	0.001	0.001	0.008	0.197	0.026	0.010	0.100
2000 m	*rho*	0.148	-0.561**	-0.206	-0.077	-0.256	-0.275	0.218	-0.213	-0.404	0.076	-0.244	-0.513*	-0.521*	-0.447*	-0.213	-0.312	-0.393	-0.203
	Sig.	0.500	0.005	0.346	0.728	0.239	0.203	0.318	0.329	0.056	0.730	0.261	0.012	0.011	0.032	0.329	0.147	0.064	0.353
Combined time	*rho*	0.183	-0.612**	-0.244	-0.060	-0.273	-0.387	0.111	-0.275	-0.356	0.075	-0.268	-0.595**	-0.626**	-0.532**	-0.275	-0.431*	-0.493**	-0.328
	Sig.	0.404	0.002	0.236	0.785	0.207	0.068	0.614	0.204	0.095	0.733	0.217	0.003	0.001	0.009	0.204	0.040	0.017	0.126

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

». Chronological Age (CA); Maturity offset (MO); Brachial circumference (Brachial C.) Brachial circumference in maximum contraction (Br.C.MC); Biacromial diameter (Biac. D); Upper limb volume (ULV); ForearmVolume (FA.V.); Handgrip Strength (HGS); Angle between blades (Angle b.blades); Chest circumference (Chest C.)

The correlations between push-ups; pull-ups; sit-ups; handgrip strength; time at 1000 m; time at 2000 m; the combined time and the paddle length; blade length; blade width; angle between blades; handgrip distance; frontal blade area; shaft diameter show that (table 5) the pull-ups correlate significantly and positively with the blade length (*rho*≤0.05); the sit-ups correlate significantly and positively with the shaft diameter (*rho*≤0.05); the handgrip strength correlate significantly and positively with the paddle length (*rho*≤0.01); the time at 1000 m correlate significantly and negatively with the handgrip distance (*rho*≤0.05) and the combined time correlate significantly and negatively with the blade length (*rho*≤0.05).

Table 5. Correlations between push-ups; pull-ups; sit-ups; handgrip strength; time at 1000 m; time at 2000 m; the combined time and the paddle length; blade length; blade width; angle between blades; handgrip distance; frontal blade area; shaft diameter.

		Push-ups	Pull-ups	Sit-ups	Handgrip strength	1000 m	2000 m	Combined time
Paddle length	*rho*	0.192	0.278	0.110	0.554**	-0.235	-0.217	-0.232
	Sig	0.381	0.200	0.617	0.006	0.280	0.319	0.286
Blade length	*rho*	0.399	0.440*	-0.380	0.143	-0.395	-0.332	-0.395
	Sig	0.060	0.035	0.074	0.516	0.062	0.122	0.062
Blade width	*rho*	0.158	0.102	-0.336	0.374	-0.130	-0.128	-0.151
	Sig	0.471	0.643	0.117	0.079	0.554	0.561	0.490
Angle b.blades	*rho*	-0.142	0.105	0.151	-0.272	0.140	0.117	0.144
	Sig	0.519	0.634	0.491	0.209	0.524	0.594	0.511
HG distance	*rho*	0.148	0.386	0.372	0.271	-0.384	-0.391	-0.402
	Sig	0.502	0.069	0.080	0.211	0.070	0.065	0.057
Frontal B. area	*rho*	0.336	0.349	-0.320	0.171	-0.301	-0.269	-0.296
	Sig	0.117	0.102	0.137	0.434	0.162	0.214	0.170
Shaft diameter	*rho*	-0.302	0.149	0.461*	0.010	0.061	-0.028	0.023
	Sig	0.161	0.498	0.027	0.965	0.782	0.900	0.918

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

». Angle between blades (Angle b.blades); Handgrip distance (HG distance); Frontal blade area (Frontal B. area)

It is also possible to verify that the years of practice correlates significantly and positively (table 6), with brachial circumference (*rho*≤0.01); brachial circumference in maximum contraction (*rho*≤0.01); chest circumference (*rho*≤0.05); upper limb volume (*rho*≤0.01); arm volume (*rho*≤0.05) and forearm volume (*rho*≤0.05); and the maturity offset correlates significantly and positively with the brachial circumference in maximum contraction (*rho*≤0.05); chest circumference (*rho*≤0.01); upper limb volume (*rho*≤0.01); arm volume (*rho*≤0.01) and forearm volume (*rho*≤0.05).

Table 6. Correlations between chronological age; years of practice; maturity offset and the stature; sitting height; body mass; % of fat mass; arm span; arm length; forearm length hand length.

		Chronological Age	Years practice	Maturity Offset
Stature	*rho*	0.111	0.168	0.591**
	Sig	0.616	0.444	0.003
Sitting height	*rho*	0.005	0.143	0.846**
	Sig	0.981	0.516	0.000
Body mass	*rho*	-0.180	0.497*	0.647**
	Sig	0.411	0.016	0.001
%Fat mass	*rho*	-0.003	0.322	-0.008
	Sig	0.990	0.134	0.972
Arm span	*rho*	0.016	0.419*	0.436*
	Sig	0.941	0.047	0.038
Arm length	*rho*	0.051	0.397	0.194
	Sig	0.818	0.061	0.376
Forearm length	*rho*	-0.006	0.335	0.225
	Sig	0.978	0.118	0.302
Hand length	*rho*	0.011	0.243	0.424*
	Sig	0.960	0.263	0.044

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 7 allow the verification of the associations between chronological age; years of practice; maturity offset and the brachial circumference; brachial circumference in maximal contraction; chest circumference; biacromial diameter; upper limb volume; arm volume; forearm volume. Is visible the significantly and positively association of years of practice with the brachial circumference (*rho*≤0.01); brachial circumference in maximum contraction (*rho*≤0.01); chest circumference (*rho*≤0.05); upper limb volume (*rho*≤0.01); arm volume (*rho*≤0.05) and forearm volume (*rho*≤0.05); and the maturity offset significantly and positively association with the brachial circumference in maximum contraction (*rho*≤0.05); chest circumference (*rho*≤0.01); upper limb volume (*rho*≤0.01); arm volume (*rho*≤0.01) and forearm volume (*rho*≤0.05).

Table 7. Correlations between chronological age; years of practice; maturity offset and the brachial circumference; brachial circumference in maximal contraction; chest circumference; biacromial diameter; upper limb volume; arm volume; forearm volume.

		Chronological Age	Years of practice	Maturity Offset
Brachial Circumference	*rho*	-0.211	0.626**	0.407
	Sig	0.334	0.001	0.054
Brachial C.MC	*rho*	-0.162	0.535**	0.520*
	Sig	0.460	0.009	0.011
Chest Circumference	*rho*	-0.102	0.461*	0.543**
	Sig	0.644	0.027	0.007
Biacromial Diameter	*rho*	-0.400	0.388	0.350
	Sig	0.059	0.067	0.102
Upper Limb Volume	*rho*	-0.151	0.527**	0.552**
	Sig	0.492	0.010	0.006
Arm volume	*rho*	-0.158	0.511*	0.551**
	Sig	0.470	0.013	0.006
Forearm Volume	*rho*	-0.307	0.453*	0.436*
	Sig	0.154	0.030	0.038

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

». Brachial circumference in maximum contraction (Brachial C.MC).

Table 8. Correlations between push-ups, pull-ups, sit-ups, handgrip strength and time at 1000 meters, time at 2000 meters and handgrip strength.

		Push-ups	Pull-ups	Sit-ups	Handgrip strength
Time at 1000 meters	*rho*	-0.403	-0.821**	-0.144	-0.349
	Sig	0.057	0.000	0.514	0.102
Time at 2000 meters	*rho*	-0.533**	-0.854**	-0.274	-0.248
	Sig	0.009	0.000	0.206	0.254
Combined time	*rho*	-0.442*	-0.840**	-0.181	-0.352
	Sig	0.035	0.000	0.409	0.099

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

The Correlations between push-ups, pull-ups, sit-ups, handgrip strength and time at 1000 meters, time at 2000 meters and handgrip strength (table 8), showed that push-ups as an association with time at 2000 meters (*rh*≤0.01) and the combined time (*rho*≤0.05), whereas the pull-ups associated with time at 1000 meters (*rho*≤0.01), time at 2000 meters (*rho*≤0.01) and the combined time (*rho*≤0.01).

Table 9. Multiple regression model of paddle length (Sitting height; Maturity offset; Handgrip strength); blade length (Chronological age; Pull-ups); blade width (Chronological age; Body mass).

Variables	r	r^2	**Adjusted** r^2	**ß**	**Std. Error**	**Std. Error estimate (SEE)**	***F***	***p***	***t***	**Significance of *t***
Constant	0.693	0.480	0.398	170.598	28.320	2.189	5.840	0.005	6.024	0.001
Sitting height	-	-	-	0.409	0.347	-	-	-	1.180	0.253
Maturity offset	-	-	-	1.177	2.179	-	-	-	0.540	0.595
Handgrip strength	-	-	-	0.049	0.114	-	-	-	0.427	0.674
Constant	0.584	0.341	0.275	62.568	7.628	1.058	5.182	0.015	8.203	<0.001
Chronological age	-	-	-	-0.983	0.493	-	-	-	-1.994	0.060
Pull-ups	-	-	-	0.088	0.037	-	-	-	2.370	0.028
Constant	0.551	0.304	0.234	20.074	3.325	0.428	4.364	0.027	6.037	<0.001
Chronological age	-	-	-	-0.381	0.201	-	-	-	-1.895	0.073
Body mass	-	-	-	0.025	0.013	-	-	-	1.951	0.065

In table 9 is possible to consult the multiple regression model for the paddle length, through the variation of the sitting height, the maturity offset and the handgrip strength; for the blade length through the variation of the chronological age and the pull-ups and for blade width through the variation of the chronological age and the body mass, it is also possible to observe some measurements of the quality of the model.

This explicative model shows that 48% of the variation in the paddle length is explained by the variation of the sitting height, the maturity offset or handgrip strength, and indicates also a prediction error somehow elevated (r^2= 0.480; SEE= 2.189; F= 5.840; p= 0.005). The equation for paddle length prediction is as follows:

Paddle length$_i$ = 170.598 + (0.409 × **Sitting height**) + (1.177 × **Maturity offset**) + (0.049 × **Handgrip strength**) + ε_i

Also indicates that the blade length can be explained by the variation in 34% of sitting height (r^2= 0.341; SEE= 1.058; F= 5.182; p= 0.015), and the paddle length prediction equation for the variation of the chronological age and the body mass is as follows:

Blade length$_i$ = 62.568 + (-0.983 × **Chronological age**) + (0.088 × **Pull-ups**) + ε_i

And shows that the blade width can be explained by the variation in 30% of the chronological age or body mass (r^2= 0.304; SEE= 0.428; F= 4.364; p= 0.027), and the blade width prediction equation for the variation of the chronological age and the body mass is as follows:

Blade width$_i$ = 20.074 + (-0.381 × **Chronological age**) + (0.025 × **body mass**) + ε_i

In table 10 are displayed the linear regression model for the paddle length through the variation of the sitting height (simplified formula), handgrip distance through the variation of the years of practice; paddle frontal area through the variation of the chronological age and Shaft diameter through the variation of the Sit-ups.

This model indicates that the paddle length can be explained by the variation in 45.8% of sitting height, and similarly indicates a prediction error somehow elevated (r^2= 0.458; SEE= 2.126; F= 17.745; p= 0.000), and the paddle length prediction equation for the variation of the sitting height is as follows:

Paddle length$_i$ = 150.780 + (0.671 × **Sitting height**) + ε_i

Indicates that 26% of the variation in the handgrip distance is explained by the variation of the years of practice, and indicates also an elevated error prediction (r^2= 0.267; SEE= 3.675; F= 7.665; p= 0.012). The equation for handgrip distance prediction is as follows:

Handgrip distance$_i$ = 66.728 + (0.988 × **Years of practice**) + ε_i

Shows us that 29% of the variation in the blade area is explained by the variation of the chronological age, and indicates also a very high prediction error (r^2= 0.293; SEE= 29.389; F= 8.694; p= 0.008). The equation for the paddle frontal area prediction is as follows:

Blade frontal area$_i$ = 1270.157 + (-40.236 × **Chronological age**) + ε_i

And also shows that 22% of the variation in the diameter of the shaft is explained by the variation of the sit-ups (r^2= 0.224; SEE= 1.403; F= 6.074; p= 0.02). The equation for the paddle frontal area prediction is as follows:

Shaft diameter$_i$ = 25.880 + (0.044 × **Sit-ups**) + ε_i

Table 10. Linear regression model of paddle length (Sitting height); handgrip distance (Years of practice); blade frontal area (Chronological age) and Shaft diameter (Sit-ups).

Variables	*r*	r^2	Adjusted r^2	ß	Std. Error	Std. Error estimate (SEE)	*F*	*p*	*t*	Significance of *t*
Constant	0.677	0.458	0.432	150.780	14.589	2.126	17.745	<0.001	10.335	<0.001
Sitting height	-	-	-	0.671	0.159	-	-	-	4.212	<0.001
Constant	0.517	0.267	0.233	66.728	1.450	3.675	7.665	0.012	460.33	<0.001
Years of practice	-	-	-	0.988	0.350	-	-	-	2.769	0.012
Constant	0.541	0.293	0.259	1270.157	210.117	29.389	8.694	0.008	6.045	<0.001
Chronological age	-	-	-	-40.236	13.646	-	-	-	-2.949	0.008
Constant	0.474	0.224	0.187	25.880	1.231	1.403	6.074	0.02	21.028	<0.001
Sit-ups	-	-	-	0.044	0.018	-	-	-	2.465	0.022

Considering the differences between national team athletes, 6 best combined times 1000 m + 2000 m (13:36 ± 0.3 min:sec) and non-national team athletes, 10 worst combined times 1000m + 2000m (16:34 ± 1.1 min:sec), Table 11.

Significant statistical differences were found with regard to the training experience ($p \leq 0.01$); hours per week ($p \leq 0.05$); brachial circumference ($p \leq 0.05$); brachial circumference in maximum contraction ($p \leq 0.01$); arm volume ($p \leq 0.05$); pull-ups ($p \leq 0.01$); time at 1000 meters ($p \leq 0.01$); the time at 2000 meters ($p \leq 0.01$) and the combined time ($p \leq 0.01$).

Of the remaining variables, four of them (arm length; blade length; handgrip distance; push-ups) are near the level of significance all the other features relating to the equipment, anthropometry and physical fitness did not present statistically significant differences despite national athletes, presenting higher mean values in all studied variables except % fat mass, forearm length and the angle between blades.

The same analysis performed between the best three combined times 1000 m + 2000 m (13:34 ± 0.09 min:sec) of the national team athletes and worst three combined times 1000 m + 2000 m (17:58 ± 1.2 min:sec) of non-national team athletes (table 12), shows the following significant statistical differences between training experience ($p \leq 0.05$); body mass ($p \leq 0.05$); brachial circumference ($p \leq 0.05$); brachial circumference in maximum contraction ($p \leq 0.05$); chest circumference ($p \leq 0.05$); arm length ($p \leq 0.05$); angle between blades ($p \leq 0.05$); pull-ups ($p \leq 0.05$); time at 1000 meters ($p \leq 0.05$); the time at 2000 meters ($p \leq 0.05$) and the combined time ($p \leq 0.05$).

Table 11. Descriptive statistics and results of the Mann-Whitney test to assess the difference between the national team athletes , six best combined times 1000 m + 2000 m (13:36 ± 0.3 min:sec) and non-national team athletes ten worst combined times 1000m + 2000m (16:34 ± 1.1 min:sec).

Variables	Units	National team (n= 6)	Non-National team (n= 10)	*U*	*p*
Training	years	5.2 ± 2.3	2.0 ± 1.6	6.500	**
Hours per week	hours	12.2 ± 2.4	8.8 ± 1.8	7.000	*
Chronological age	years	15.58 ± 0.2	15.56 ± 0.5	24.500	*n.s.*
Estimated mature stature	%	96.5 ± 2.4	96.3 ± 2.5	29.500	*n.s.*
Maturity offset	years	1.9 ± 0.6	1.6 ± 0.4	22.000	*n.s.*
Stature	cm	173.4 ± 7.6	173.2 ± 7.2	29.000	*n.s.*
Sitting height	cm	92.1 ± 3.6	90.8 ± 2.7	25.000	*n.s.*
Body mass	kg	65.9 ± 7.1	61.1 ± 6.9	18.000	*n.s.*
Fat mass	%	15.5 ± 3.7	15.7 ± 3.9	29.500	*n.s.*
Arm span	cm	181.7 ± 10.9	175.9 ± 5.3	24.000	*n.s.*
Arm	cm	35.5 ± 2.1	33.5 ± 1.8	14.000	*n.s.*
Forearm	cm	28.4 ± 1.7	28.5 ± 0.8	28.500	*n.s.*
Hand	cm	19.0 ± 0.9	18.6 ± 0.7	20.000	*n.s.*
Brachial	cm	28.1 ± 1.4	26.1 ± 1.7	9.000	*
Brachial maximum contraction	cm	31.4 ± 1.7	29.3 ± 2.1	9.000	*
Chest	cm	95.2 ± 6.3	89.7 ± 4.3	15.000	*n.s.*
Biacromial	cm	38.5 ± 1.7	37.9 ± 1.9	24.500	*n.s.*
Upper limb volume	L	3574.7 ± 548.1	3103.5 ± 367.1	16.000	*n.s.*
Arm volume	L	2379.6 ± 382.5	2011.8 ± 258.5	11.000	*
Forearm volume	L	1195.1 ± 175.0	1091.6 ± 123.6	21.000	*n.s.*
Paddle length	cm	213.3 ± 1.3	211.7 ± 3.7	22.000	*n.s.*
Blade length	cm	48.7 ± 0.6	47.6 ± 1.5	13.500	*n.s.*
Blade width	cm	15.8 ± 0.2	15.7 ± 0.6	28.500	*n.s.*
Handgrip distance	cm	72.9 ± 4.5	68.7 ± 4.3	13.000	*n.s.*
Frontal blade area	cm^2	649.0 ± 13.8	633.6 ± 41.5	17.000	*n.s.*
Angle between blades	grº	58.3 ± 8.5	60.2 ± 10.5	29.000	*n.s.*
Shaft diameter	mm	29.6 ± 0.8	29.1 ± 1.4	28.000	*n.s.*
Push-ups	reps	40.2 ± 7.0	27.5 ± 14.1	12.500	*n.s.*
Pull-ups	reps	16.3 ± 3.6	4.2 ± 2.5	0.000	**
Sit-ups	reps	75.0 ± 0.0	66.3 ± 19.1	24.000	*n.s.*
Handgrip strength	kg/f	47.5 ± 9.6	42.3 ± 5.7	19.500	*n.s.*
1000 meters	min:s	4:25 ± 0.1	5:45 ± 0.4	0.000	**
2000 meters	min:s	9:23 ± 0.1	10:55 ± 0.7	0.000	**
Combined time	min:s	13:36 ± 0.3	16:34 ± 1.1	0.000	**

n.s. (not significant), * ($p\leq 0.05$), ** ($p\leq 0.01$)

Table 12. Descriptive statistics and results of the Mann-Whitney test to assess the difference between the best three combined times 1000 m + 2000 m (13:34 ± 0.09 min:sec) of the national team athletes and worst three combined times 1000 m + 2000 m (17:58 ± 1.2 min:sec) of non-national team athletes.

Variables	Units	National team (n= 3)	Non-National team (n= 3)	*U*	*p*
Training	years	5.3 ± 0.6	2.6 ± 1.5	0.000	*
Hours per week	hours	11.6 ± 2.1	9.3 ± 2.5	2.000	*n.s.*
Chronological age	years	15.70 ± 0.2	15.70 ± 0.1	4.000	*n.s.*
Estimated mature stature	%	97.5 ± 1.5	96.5 ± 1.3	3.000	*n.s.*
Maturity offset	years	2.1 ± 0.8	1.4 ± 0.5	2.000	*n.s.*
Stature	cm	174.4 ± 9.5	171.3 ± 6.6	4.000	*n.s.*
Sitting height	cm	92.8 ± 5.2	88.6 ± 3.5	2.000	*n.s.*
Body mass	Kg	67.0 ± 7.5	56.7 ± 3.6	0.000	*
Fat mass	%	14.6 ± 2.6	15.8 ± 4.8	3.500	*n.s.*
Arm span	cm	183.9 ± 11.6	176.3 ± 1.1	3.000	*n.s.*
Arm	cm	36.5 ± 1.7	33.4 ± 0.3	0.000	*
Forearm	cm	28.9 ± 1.8	28.7 ± 0.3	2.000	*n.s.*
Hand	cm	19.3 ± 1.0	18.2 ± 0.3	1.000	*n.s.*
Brachial	cm	28.2 ± 1.4	25.4 ± 1.1	0.000	*
Brachial maximum contraction	cm	32.0 ± 2.2	28.1 ± 1.6	0.000	*
Chest	cm	96.4 ± 6.6	87.4 ± 2.5	0.000	*
Biacromial	cm	38.2 ± 1.1	37.3 ± 2.5	3.000	*n.s.*
Upper limb volume	L	3713.4 ± 718.5	2889.0 ± 237.9	1.000	*n.s.*
Arm volume	L	2475.5 ± 508.9	1866.0 ± 140.4	1.000	*n.s.*
Forearm volume	L	1237.9 ± 217.1	1023.0 ± 98.1	2.000	*n.s.*
Paddle length	cm	212.7 ± 1.7	208.3 ± 4.1	2.000	*n.s.*
Blade length	cm	48.5 ± 0.8	45.9 ± 1.9	1.000	*n.s.*
Blade width	cm	15.7 ± 0.3	15.0 ± 0.6	2.000	*n.s.*
Handgrip distance	cm	75.1 ± 4.5	71.3 ± 5.9	2.000	*n.s.*
Frontal blade area	cm^2	647.0 ± 16.1	599.6 ± 41.6	2.000	*n.s.*
Angle between blades	gr^o	51.1 ± 0.5	68.4 ± 5.1	0.000	*
Shaft diameter	mm	29.3 ± 0.6	29.0 ± 1.7	4.000	*n.s.*
Push-ups	reps	41.0 ± 7.8	22.3 ± 14.4	1.000	*n.s.*
Pull-ups	reps	14.3 ± 3.7	2.7 ± 0.6	0.000	*
Sit-ups	reps	75.0 ± 0.0	75.0 ± 0.0	0.000	*n.s.*
Handgrip strength	kg/f	47.7 ± 12.6	37.7 ± 5.9	2.000	*n.s.*
1000 meters	min:s	4:19 ± 0.04	5:54 ± 0.4	0.000	*
2000 meters	min:s	9:15 ± 0.02	11:42 ± 0.8	0.000	*
Combined time	min:s	13:34 ± 0.09	17:58 ± 1.2	0.000	*

n.s. (not significant), * ($p \leq 0.05$)

5. DISCUSSION

The aim of this study was to identify the anthropometric characteristics of young male sprint kayak paddlers who better associate with physical fitness and the performance obtained in real race conditions. Offering the anthropometric profile of the young male paddler, and revealing that athletes with slightly larger upper body dimensions and better results in pull-up test have better performance in flatwater racing and the possibility of use this information as a guide in the process of talent identification. Also enables a less empirical approach to the selection of paddle length and may allow coaches and athletes to explore the feasibility of customizing the dimensions of the paddle.

Building an athlete in order to reach his maximum possible performance is a long process with many factors that influence and determine a sprint paddler's overall performance, such as technique; physiological characteristic's (strength, cardiovascular efficiency etc.); equipment (clothing, boat, paddle etc.); personality (emotion and motivation); health; tactics & strategies (employed by the performer and fellow contestants); diet/nutrition and environmental conditions.

Several of the factors are interrelated, for example, improved fitness is likely to facilitate better technique and although it may be possible to have a good efficient paddling technique without the physical fitness to sustain it for very long.

Thereby some factors are totally dependent upon one another, for instance, is difficult to have a properly technique with poorly designed or inadequate equipment (Cox, 1992).

According to Alacid et al., (2011*b*), the young male paddlers have general anthropometric characteristics similar to young athletes who practice other sports, but with superior upper body dimensions. The present study obtained very similar results to a study conducted by Alacid et al., (2011*c*) with Spanish kayakers (15.6 ± 0.6 years).

Spaniards athletes have relatively higher values with respect to body mass (68.6 ± 7.1 kg), and fat mass % (24.5), fat mass % was calculated using the method of Kerr

(1988), with the values obtained in the remaining variables very close to those obtained in our study.

The comparison of anthropometric characteristics of young male paddlers (present study; Alacid et al., 2011c) and Olympic paddlers (Ackland et al., 2003) are displayed in Figure 3.

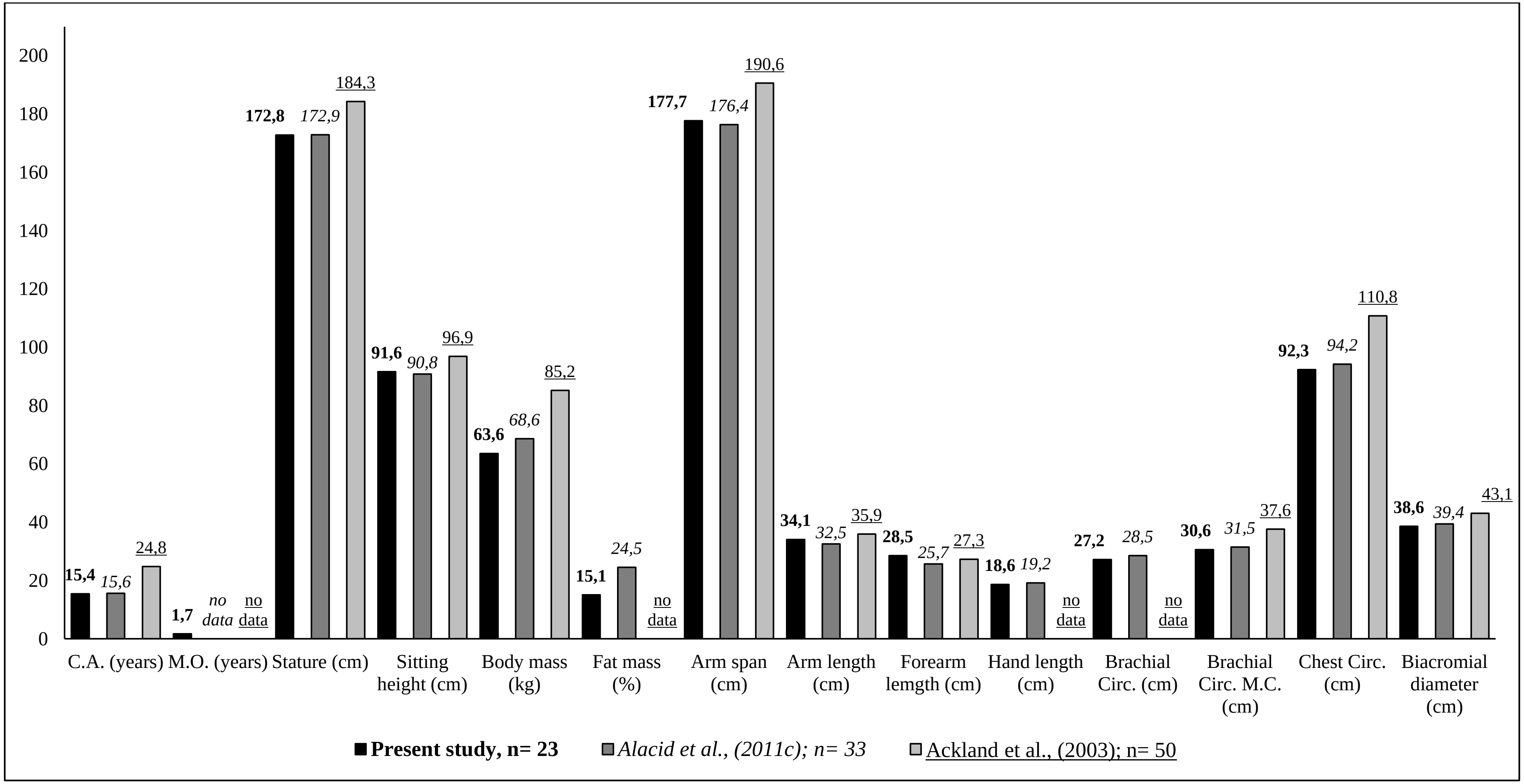

Figure 3. Comparison of the means obtained for each anthropometric characteristics reported in present study; Alacid et al., (2011c) and Ackland et al., (2003).

In a study that aimed to find anthropometric and physiological predictors in 1000m kayak performance in young adolescents Forbes, Fuller, Krentz, Little & Chilibeck, (2009) , has reported that the anthropometric data, age (15 ± 1 years), stature , sitting height, and arm span were all significantly ($p< 0.05$) correlated to performance, but body mass was not. All the physiological and strength variables were significantly ($p< 0.05$) correlated to 1000m performance. This authors also stated that the overall best predictor of performance was bench press 1RM ($r= -0.92$).

If we compare our results with those obtained in a study conducted by Alves & Silva (2009), in the Portuguese male (19.6 ± 9.1 years) kayak national team of 2008, it is possible to observe that the main differences are in terms of stature (178.8 ± 6.6 cm), sitting height (95.9 ± 3.4 cm) and body mass (80.3 ± 7.6 kg), with adults athletes approximately 17 kg heavier than the young paddlers. Concerning the arm span young athletes have similar values to those of the senior (180.6 ± 6.4 cm) national team showing that adult kayakists have a greater arm span around 3 cm.

The associations found between better performances at 1000m and body mass ($rho\leq 0.05$), brachial circumference ($rho\leq 0.01$), brachial circumference in maximum contraction ($rho\leq 0.01$), chest circumference ($rho\leq 0.01$), upper limb volume ($rho\leq 0.05$) and arm volume ($rho\leq 0.01$), seems to suggest these variables as indicators of talent identification; this information can serve as a starting point to improve already existing batteries for assessing young paddlers and helping to the detection of talents, namely anthropometric and fitness measurements that differentiate the best of the rest.

For example, the statistically significant differences found for body mass ($p\leq 0.05$); brachial circumference ($p\leq 0.05$); brachial circumference in maximum contraction ($p\leq 0.05$); chest circumference ($p\leq 0.05$); arm length ($p\leq 0.05$); angle between blades ($p\leq 0.05$); pull-ups ($p\leq 0.05$) among the three best and the three worst athletes, seems to corroborate the possibility of using this information in future assessment batteries.

Regarding the equipment is possible only to compare the results obtained with studies in adult kayakers (Ong *et al.*, 2005; Diafas *et al.*, 2012). With respect to predictive models of equipment set-up, our results are in accordance with Ong *et al.*,

(2005) and Diafas *et al.*, (2012) since the regression analysis in our study also showed a significant relationship between anthropometric variables and equipment set-up. The predictive model for paddle length, derived from total sample assessment, shows that 48% of this parameter is explained by the variation of the sitting height, maturity offset and handgrip strength (r^2= 0.480; SEE= 2.189; F= 5.840; p= 0.005).

It is also possible to use a predictive model for paddle length slightly less powerful 45.8%, showing that paddle length can be explained by the variation of sitting height (r^2= 0.458; SEE= 2.126; F= 17.745; p= 0.000). Despite being less explanatory may be of greater utility for coaches since it is easier to interpret and use in the field, once it requires minimal technical apparatus. The remaining linear regressions also revealed significant ($p < 0.05$) relationships between measures of body size and shaft diameter, blade frontal area, handgrip distance, blade width and blade length, accounting respectively for 22%, 29%, 26%, 30% and 34% of the variance.

To mention also that the equation to determine the handgrip distance (Handgrip $\text{distance}_i = 66.728 + [0.988 \times \text{Years of practice}] + \varepsilon_i$), may prove to be equally useful to coaches, because may bring a more scientific approach than the current method of selecting the handgrip distance. Because it is very simple to use, requiring only the years of practice of the athlete.

Currently the most used method suggests that the correct distance between handgrips is determined by keeping the shaft of the paddle above the head with the arms horizontal and forearms vertically forming a right angle with each other (Rademaker, 1977; quoted by Ong et al., 2005).

In the study of Ong et al., (2005), stature were the anthropometric characteristics most associated with the equipment set-up for male sprint paddlers serving as a predictor of hand grip distance (r^2= 0.541; $p < 0.001$) and foot bar distance (r^2= 0.589; p< 0.001) this author reports that other regression analyses showed significant (p< 0.05) relationships between measures of body size and both paddle length and blade length, however only accounting for 20% and 25% of the variance in the dependent variables.

The author considered that the positive relationship between these set-up parameters and height, biacromial breadth, chest girth, arm length and arm span was notable. In its turn Diafas et al., (2012) reported that the total arm length ($r = 0.33$, $p < 0.01$); arm span ($r = 0.33$, $p < 0.01$); total leg length ($r = 0.33$, $p < 0.01$); stature ($r = 0.33$, $p < 0.01$) and body mass index ($r = 0.44$, $p < 0.001$); body mass ($r = 0.44$, $p < 0.001$) and lean body fat ($r = 0.44$, $p < 0.001$) were significantly correlated with paddle length.

Comparisons' of the equipment set-up of young male paddlers (present study), Olympic paddlers (Ong et al., 2003) and adult greek athletes (Diafas et al., 2012) are presented in Figure 4.

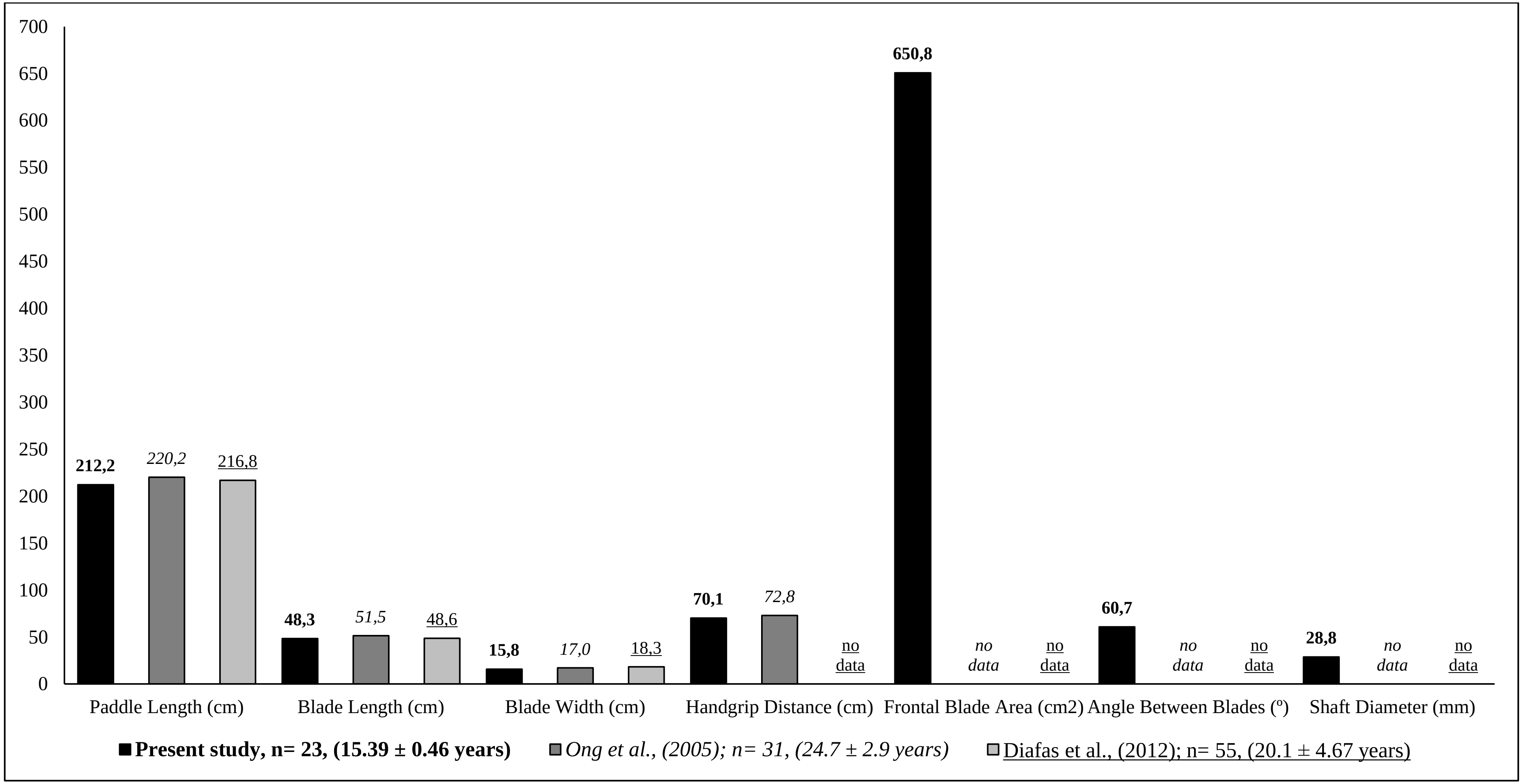

Figure 4. Comparison of the means obtained for the equipment set-up characteristics reported in Fernandes et al., (2013); Ong et al., (2005) and Diafas et al., (2012).

Patent in the previous figure are the differences in the dimensions of the equipment, particularly regardin the length and width of the blade. Should be noted that the study of Ong et al., (2005) seems to display measures consistent with a model of paddle commonly used by adult and "expert"athletes.

On the contrary the study of Diafas et al., (2012) that shows values, o some extent, difficult to understand, disclosing a blade length practically equal to the juvenile athletes in the present study, but a blade width substantially superior than the elite athletes observed by Ong et al., (2005).

It is also noted that the dimensions of the length and width of the blade verified in this study (length of blade – 48.3 ± 1.2 cm; width of blade – 15.8 ± 0.5 cm) are somewhat similar to a model of paddle (Model C) suggested by a well-known manufacturer of paddles worldwide.

This manufacturer produces three models of paddles specifically for young athletes: Model A (length of blade – 45.2 to 46.5 cm; width of blade – 13.3 to 15.0 cm), Model B (length of blade – 45.0 to 45.3 cm; width of blade – 14.5 to 15.1 cm) and Model C (length of blade – 48.4 to 48.7 cm; width of blade – 15.2 to 15.5 cm). Also according to the manufacturer this models are exact copies of the adult models, with characteristics and mechanics of the paddle specifically designed to fit children's physiology.

Another important fact to mention related to the equipment, is that their selection may also be closely linked with the paddling technique, according to Rosini (1991), quoted by Cox (1992), a double paddle is constituted by two blades which are arranged on distinct plans at an angle which may vary according to the preferences of the athlete, and can go up to 90°, in order to offer the least possible resistance to a contrary wind and to thereby facilitate its entry into the water.

The mean angle observed in our study is 60.7º however this value varies between 43.1 and 74.2° which may indicate that athletes paddling with angles lower than 60º may have a poor technical gesture which can be translated in the faulty use of trunk rotation, as suggested by Hernández (1993).

For Hernández (1993), the paddling technique is divided into two phases (air and aquatic phase), with several sub-phases (attack sub-phase, pull sub-phase and exit sub-phase). The attack-phase is characterized initially by a horizontal position of the paddle, which ends with the entry of the blade into the water (Figure 5).

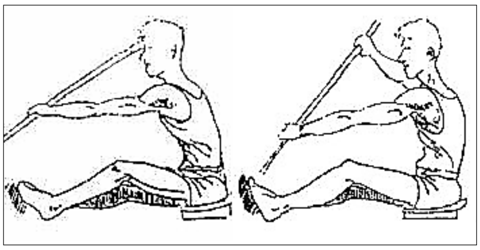

Figure 5. Attack sub-phase illustration (Adapted from http://www.kayaksport.net/technique.html).

The pull sub-phase begins when the blade enters the water, in this situation the force is applied in water by bending the upper limb performing the pull, and by rotating the trunk and the shoulder girdle (Figure 6).

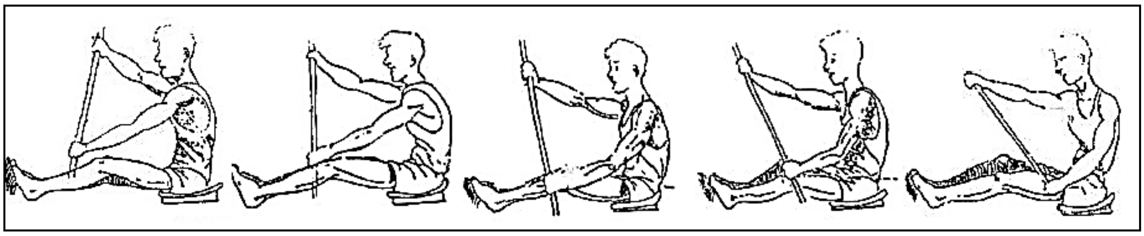

Figure 6. Pull sub-phase illustration (Adapted from http://www.kayaksport.net/technique.html).

The exit sub-phase begins when the the paddle surpasses the body, the paddle is removed from water due to rotation of the trunk, about 60º, for carrying out the next attack sub-phase and due to the upper limb which had performed the pull and is now flexed at an angle of about 90º, while the upper limb that carries the impulse is lowered and the pressure exerted on the footrest (Figure 7).

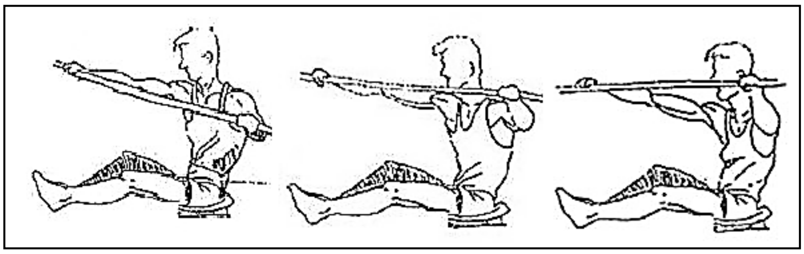

Figure 7. Exit sub-phase illustration (Adapted from http://www.kayaksport.net/technique.html).

In our opinion, this information can prove to be quite useful for coaches and athletes, however the descriptive knowledge of the technique may not be sufficient. Since an athlete's performance depends on the interactions between a large numbers of variables, it becomes difficult to determine which element of technique that matters most to the final result (Hernández, 1993).

Therefore it is necessary extensive knowledge of some of those factors, such as duration of the phases of the paddling technique or the entry angle of the paddle on water. For instance, Cox, (1992), states that paddling rate is independent of paddling frequency, since with increasing the frequency, the athlete may maintain the percentage of time it takes to perform each of the paddling phases, and Sanders & Kendal (1992), showed that best athletes attained higher paddling frequencies.

These were achieved by reducing both the aquatic and air phase. In both study’s, the air phase of the best athletes had duration of about 31% and the aquatic phase of about 69% of total paddling time (Cox, 1992; Sanders & Kendal, 1992). More recently Begon, Mancini, Durand & Lacouture (2003) obtained 57.5% for the aquatic phase and 42.5% for the air phase.

In the same manner and relatively speaking to the angles of entry and exit of the blade in the water, according to a study of Baker, Rath, Sanders, & Kelly, (1999), with male kayakers, the best entry angle of the blade in the water was on average 38.2 ± 4.3 degrees, the exit angle of the blade from the water stood at 23.4 ± 2.9 degrees.

Thus detailed knowledge of technique combined with knowledge of the determining factors for optimal sports performance, could assist coaches in the various decisions that may be taken to improve the performance of their athletes. Whether related to equipment, anthropometry or any other factor determining performance.

If we focus on physical fitness, and taking into account the results obtained by Baptista, Silva, Marques, Santos, Vale, Ferreira, Raimundo & Moreira, (2011) a representative study of the Portuguese population, in which young boys (14.3 ± 2.4 years) have positive values for physical fitness, more specifically 63.1% meets the requirements in abdominal strength (42.1 ± 22.1 reps) and 56.4% in the push-up test (14.9 ± 9.1 reps), the results of our study are far superior, (67.6 ± 16.9 reps) for the sit-up test and (34.1 ± 11.7 reps) for the push-up test.

The results for the pull-up test (9.8 ± 6.1 reps) in our study in conjunction with the observed association between better performances at 1000m and pull-ups (*rho*≤ 0.01) suggest that this is a test of specific strength in canoeing, however it is not possible to compare the results of our study with data from the *Observatório Nacional da Actividade Física e do Desporto* study. The same applies to the hand grip strength, however the values obtained for the young paddlers (44.1 ± 6.7 kg/f) are close (48.1 ± 8.5 kg/f) to those achieved by the Portuguese adult population (38.0 ± 12.6 years).

Furthermore the handgrip strength shown associations with paddle length (*rho*≤ 0.01); maturity offset (*rho*≤ 0.01); stature (*rho*≤ 0.01); sitting height (*rho*≤ 0.01); body mass (*rho*≤ 0.01); biacromial diameter (*rho*≤ 0.01); brachial circumference (*rho*≤ 0.01); brachial circumference in maximum contraction (*rho*≤ 0.01); chest circumference (*rho*≤ 0.05) and upper limb volume (*rho*≤ 0.01).

This variable could be used as a general indicator for overall muscle strength, once Wind, Takken, Helders & Engelbert, (2010) showed that there is a strong correlation between grip strength and total muscle strength. Santos, Ferreira, Costa, Guimarães & Ritti-dias, (2011) showed also that handgrip strength was correlated with the indicator of muscle mass in the three maturational stages, and according to the results obtained in this study, higher levels of force are observed in subjects with increasing age, which is consistent with the available studies.

In a study of Rauch, Neu, Christina, Wassmer, Beck, Rieger-Wettengl, Rietschel, Manz & Schoenau, (2002) and conducted with 315 children and adolescents (6 to 19 years) showed similarly higher levels of handgrip strength with increasing age, being also observed a correlation between strength and stature.

Physical performance is related to biological maturation during adolescence and is more pronounced when boys of contrasting maturity status are compared; generally athletes of different competitive levels are characterized by average or advanced in maturity status (Malina et al., 2004b; Beunen & Malina, 2008).

Furthermore it is known that isometric strength increases with age during childhood and the transition into adolescence, at approximately 13 years, strength development accelerates considerably in boys, longitudinal data show adolescent spurts in strength, motor performances, and absolute aerobic power in boys (Beunen & Malina, 2008).

In our study as to maturity offset, the paddlers have already reached the peak height growth velocity in stature to 1.7 ± 0.5 years, and despite this variable have shown associations with paddle length (*rho*≤ 0.01); handgrip strength (*rho*≤ 0.01); stature (*rho*≤ 0.01); sitting height (*rho*≤ 0.01); body mass (*rho*≤ 0.01); arm span (*rho*≤ 0.05); hand length (*rho*≤ 0.05); brachial circumference (*rho*≤ 0.01); brachial circumference in maximum contraction (*rho*≤ 0.01); chest circumference (*rho*≤ 0.05) and upper limb volume (*rho*≤ 0.01), showed no association with performance. Also it was predicted a estimated mature stature of 96% indicating that paddlers are close to adult stature.

6. CONCLUSION

The involvement of children in sport today is a widespread and a multifaceted reality; all the training process should be well-targeted and well planned steps because scientific research has identified that it takes at least 10 years, or 10,000 hours for talented athletes to achieve sporting excellence (Ericsson et al., 1993). Therefore, there are no short cuts. There are two ways in which young athletes can improve their performance: training and growth.

Thereby young athlete are subjected to large changes which determine different effects on training., and so it's necessary to encounter the specific individualities of the youth, so that he can make the most in terms of increasing the sport potential, aiming to produce success at long-term. There's a need to improve the right research, the standards of training and development, and hopes to those who can make the most difference for youth. Encouraging healthy coaching, training, and competition practices overall (Bergeron, 2010).

To our knowledge this study is the first attempt to associate the anthropometric characteristics of young paddlers with variables such as equipment, physical fitness and also performance, and according to our perspective the results obtained: (1) offers the anthropometric profile of the young male paddler, and uncover that athletes with slightly larger upper body dimensions and better results in pull-up test have better performance in flatwater racing. Previous evidence, could be used as a guide in the process of talent identification, (2) also the predictive models of equipment dimensions, may be used more objectively in initial equipment set-up selection, allowing coaches and athletes to explore the feasibility of customizing the dimensions of the paddle.

Seeming certain that this work may pave the way for similar studies with the possibility of using other methodological apparatus, such as the DEXA technology to assess the upper limb volume, the air displacement plethysmography to analyze the body composition and the possibility of an experimental study designed to assess the effect of the paddle technique in equipment selection, as well as enable to understand the reliability of the use of predictive models for the selection of the paddlers equipment.

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