Faculty of Physical Education and Sport Sciences

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YOUTH ROLLER HOCKEY PLAYERS:

Characteristics by Playing Position

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

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“Há dias em que o cansaço se torna efémero e a glória eterna”, e isto meus amigos, “isto é que é vida!”

Um muitíssimo obrigado!

ABSTRACT

Purpose: The present study examined the association of maturity and anthropometric characteristics with performance (field and laboratory tests) in young roller hockey players, considering position as a potential source of inter-individual variability.

Method: Seventy three Portuguese [goalkeepers (*n* = 13), defenders (*n* = 29), attackers (*n* = 31)], highly trained male athletes (CA: 15.41 ± 0.64 years; SA: 16.41 ± 1.47 years; stature: 169.9 ± 6.9 cm; body mass: 63.9 ± 11.3 kg) performed eight field tests (squat and counter movement jump, standing long jump, sit-ups, hand-grip, 2-Kg ball throw, 25m dash, 20-m multi-stage continuous shuttle run) and three laboratory tests (incremental maximal test on a motorized treadmill, 30-s Wingate test, isokinetic dynamometry at $60°\cdot s^{-1}$).

Results: Cross-sectional analysis revealed differences ($p < 0.05$) in body size, lower limb explosive strength, short-term field and laboratory tests and aerobic endurance characteristics, between the outfield position groups and goalkeepers. Estimates for body mass exponents from the separate allometric models for hand grip strength (0.639), 2 Kg ball throw (0.453), peak O_2 uptake (0.600), WAnT peak output (0.952) and peak torques (0.386 – 0.598) seemed to be specific of the sport. After considering scaling, for the obtained body mass exponents, variation by playing position was not significant.

Conclusion: Functional performance of adolescent roller hockey players is mostly mediated by corresponding changes in overall body mass. Finally, variation by playing position is attenuated when functional performance is normalized using allometric models.

Key words: *Young athletes; Biological maturation; Growth; Functional fitness; Allometry*

LIST OF CONTENTS

LIST OF TABLES

INTRODUCTION

Roller or Rink-hockey is certainly the sport which conquered mores titles in Portugal whether on national teams or in clubs competitions. Roller or Rink-Hockey is played on a rectangular rink with minimum size of 34x17 m, and the maximum size of 44x22 m. The surface is leveled and smooth, surrounded by a barrier of one meter. The front frame of the goal cage has a distance from the floor to the inner edge of the cross-bar of 105 cm and the distance between the inner edges of the goal-posts of 170 cm. The official ball is made of pressed cork, weighs 155 g, is perfectly spherical and has a 23 cm circumference. The players must wear four-wheeled squad skates (in contrast to ‘inline hockey’) and use a two-sided stick to play the ball. International games have two periods of 20 minutes for seniors and under-20, and 15 minutes for under-17.

The international age groups in males are seniors, under-20 and under-17. Every year the national teams have an international tournament which could be a European Cup or a World Cup, except Under-17 that has a European Cup every year. There are two competitions for clubs, the most important is the European League and the other one is the CERS Cup. In Portugal the age groups are organized since very young ages, there are under-8 (*Bambis, 6-7 years-old*), under-10 (*benjamins, 8-9 year-old*) and under-12 (*escolares, 10-11 year-old*), those age groups do not have national competition, and the games have four periods of 8 minutes. In under-14 (infantiles, *12-13 year-old*) and under-16 (initiates, *14-15- year-old*) starts the national competition (National championship), which has the same format that is used in under-18 (juveniles, *16-17 year-old*) and under-21 (juniors, *18-20 year-old*), however the duration of the games is not the same, two periods of 15 minutes for Under-14 and under-16, two parts of 20 minutes for under-18 and 25 minutes for under 21. To achieve the national championship the clubs need to achieve a good classification on the regional championship. Above the age of 21, players are categorized as seniors and the match has the same duration that juniors had. In all age groups, the game is played by two teams of five players each (four field players and one goalkeeper).

This sport was popular in nearly 60 countries worldwide and was included in the program of the 1992 Barcelona Olympic Games, where Portugal obtained the 4th position. There were no subsequent Editions. Nevertheless, the popularity of the sport continues to grow in Europe. Roller hockey is part of the Portuguese Skating Federation along with figure skating and in-line skate racing. Registered participants numbered 8,734 pre-juniors, 986 juniors, in a total of 11,151 in 2011 (IDP – Instituto do Desporto de Portugal, 2011). Field hockey is one of the smallest Portuguese sport federations with only 1586 participants, while ice hockey is not institutionally organized in Portugal.

As in other team sports, the performance structure of the game is complex (Mendo & Argilaga, 2002). Match analysis of seniors indicated high intensity non-continuous actions; rolling accounted for 71% of match time while sprinting and pushing accounted for 4% and 14%, respectively (J. C. Kingman & R. Dyson, 1997). Rolling was defined as one or two utility strides used to maintain speed or to adjust position with almost no additional effort and pushing as a forward or backward propulsive movement.

The metabolic pathways required or other physiological capacities more important to be successful in this sport are described by Ares (2005): The roller hockey is a sport that requires intermittent exercise with short actions with different intensities, in many cases maximal or submaximal with also short frequent pauses, which still difficult the total recovery of the functional systems allowing a determined recovery between efforts, avoiding the accumulation of fatigue and total depletion of the player. There are team sports somehow similar to roller hockey that defined very well the needs to attain the success. A successful field hockey player has to be able to perform successive short all-out sprints (Cox, Miles, Verde, & Rhodes, 1995). The intermittent nature of, and the many changes of direction during, match play underscores the importance of highly developed sprint capacity and performance in repeated sprints, as well as on an outstanding slalom sprint performance and interval endurance capacity of elite player (Elferink-Gemser, Visscher, van Duijn, & Lemmink, 2006b; Lemmink, Verheijen, & Visscher, 2004), or, various physiological attributes contribute to successful sport and athletic performance with the combined interaction of the aerobic and anaerobic energy pathways, muscular strength and power, flexibility, and balance being important to the success of ice hockey athletes (Cox et al., 1995). Studies on roller hockey tell us that under simulated game conditions among 14 Spanish players 20-32 years of age, lactate concentration and heart rate were, on average, 4.20 ± 0.95 $mmol \cdot l^{-1}$ and 163.5 ± 10.4 $beats \cdot min^{-1}$, respectively (Bonafonte, Pérez, & Marrero, 1994). In ice hockey, the selected players (the best ones) were taller, heavier and more mature than their peers (Sherar, Baxter-Jones, Faulkner, & Russell, 2007). Excess body fat mass, as would be represented by a higher percent body fat, would effectively reduce skating speed by contributing to the mass that must be moved on the ice but not contributing to force production (Burr et al., 2008) .It is important to note that in ice hockey, a wide range of inter-individual variability is typically observed both in young (Burr et al., 2008) and adult (Cox et al., 1995) players, differences in physiological profile by playing position is also observable in this sport, according to Burr et al. (2008) attackers have a significantly greater relative aerobic power than defenders or goalkeepers as well as lower percentage of body fatness. In other hand defenders had a significantly greater relative aerobic power than goalkeepers, in the same study it is supposed to rank the athletes for an NHL draft, and the variables which correlate better with this rank were the anthropometry for attackers, and peak anaerobic power and fatigue index for defenders. On a study conducted by Leone, Leger, Larivinderi, and Comtois (2007), with male elite ice hockey players a specific, valid and reliable field test for the prediction of VO_{2max} in ice hockey players, determine that their VO_{2max} vary between 53.4 ± $6.34 ml \cdot kg^{-1} \cdot min^{-1}$. In field hockey players are reported specific tests of function, skill, tactics and comparisons of elite and sub-elite players on anthropometric, physiological, technical, tactical and psychological variables (Elferink-Gemser, Visscher, Richart, & Lemmink, 2004; Lemmink, Elferink-Gemser, & Visscher, 2004).

The most discriminating variables between elite and sub-elite field hockey players were tactics for ball possession, motivation and performance in a slalom dribble test. A subsequent analysis with talented players aged 12-19 years indicated percentage body fat, training hours and motivation as significant predictors of longitudinal changes in an interval shuttle-run test (Elferink-Gemser, Visscher, van Duijn, & Lemmink, 2006a).

In the context of team sports, the literature often examines the variation by competitive level but also by playing position (Abdelkrim, Chaouachi, Charmari, Chttara, & Castagna, 2010; Burr et al., 2008; Coelho e Silva et al., 2010; Tan, Polglaze, Dawson, & Cox, 2009). Coelho e Silva et al. (2010) focused the analysis only on outfield soccer players aged 14 years and considered defenders, midfielders, forwards in junior soccer players. In basketball, the literature consensually adopted the taxonomy of guards, forwards and centers (Drinkwater, Pyne, & McKenna, 2008).

Taking into account the lack of studies in roller hockey, the fact that this sport is only played by 4 outfield players, and also the fact that developmental changes in functional characteristics are still limited in the literature which particularly does not consider variation by playing position, it is necessary to verify if there are differences in history of training, growth, biological maturation, and on functional fitness among player positions (goalkeepers, defenders and attackers) at the time of specialization.

STATE OF THE ART

Age and Maturation

Adolescent athletes within a sport tend to be relatively homogeneous in training history, functional capacity and sport specific skills, but variation in size and biological maturation may be considerable Malina, Bouchard, and Bar-Or (2004) .

Chronologic age is the common reference in studies of growth and performance. However, chronological age is of limited utility in the assessment of growth and maturation (Malina et al., 2000). The range of variability among individual of the same chronological age in somatic and biological growth, and performance is large, especially during the pubertal years (Malina, Eisenmann, Cumming, Ribeiro, & Aroso, 2004).

The most commonly used indicators of biological maturation include sexual, skeletal and morphological (somatic) maturity. Stature and body mass are two of the body dimensions used primarily to monitor growth of children and adolescents (R. Malina et al., 2004). It is expected that children become taller, heavier with age, and the size attained at a given age (status) and rate of growth (progress) are monitored relative to growth charts (R. Malina et al., 2004). The growth rate of stature is highest during the first years of life then gradually declines until the onset (take-off) of the adolescent growth spurt (about 12 years in boys) (R. Malina et al., 2004). With the spurt, growth rate increases, reaching a peak (peak heigh velocity, PHV) at about 14 years in boys, and then gradually declines and eventually ceases with the attainment of adult stature (R. Malina et al., 2004; Tanner, 1962) Longitudinal data allows estimates of when adolescent growth spurts begins, and when maximal growth occurs during the spurt. It can provide an indication of the intensity (PHV) and timming (age at PHV) of the adolescent growth spurt. The estimation of the individual growth curves is usually done fitting non-linear models on estimate velocity from the longitudinal data (G. Beunen & Malina, 1988).

The fitting of these models are also applicable to estimate growth curves in other somatic indicators (e.g., sprinting, strength, peak aerobic power) (Geithner et al., 2004;

Philippaerts et al., 2006) . Children who experience their growth spurts earlier tend to have somewhat greater PHV, whereas the growth spurts of average and late-maturing children occur correspondingly later and are somewhat lesser magnitude (Malina et al., 2004).

The decline in relative fatness is a function of the marked increase in fat-free mass (FFM) during the spurt, so that fat mass (FM), though increasing slightly, constitutes a smaller percentage of body weight at this time. There is variation in the distribution of subcutaneous fat within each extremity during adolescent, in contrast to skinfolds on the extremities, the two trunk skinfolds (subscapular and suprailiac) show different trends relative to PHV (Malina et al., 2004).

During adolescence, there is considerable variation in size and performance due to interindividual differences in biological maturation. Players who were classified 'advanced' in maturation tended to have more FFM be taller, heavier, stronger, more powerful and faster than 'delayed' players (Figueiredo, Goncalves, Coelho-e-Silva, & Malina, 2009; Malina, 2011), but Some advantages such as body size are only temporary (Malina et al., 2005). That boys advanced in maturity status have larger FFM is in part a function of their larger body size. When FFM is expressed per unit stature, the difference between maturity groups is reduced but boys advanced in maturity status tend to have more FFM per unit body size. FFM increases quite rapidly, whereas the FM shows virtually no change. Hence, fat comprises a smaller percentage of body weight as the relative contribution of FFM to body weight as the relative contribution of FM to body weight increases (Malina et al., 2004).

Peak velocity for leg length occurs earlier than that for stature and peak velocity for sitting height or trunk length occurs after that for stature. Rapid growth of the lower extremities is thus characteristics in the early part of the adolescent spurt. It is of interest that the estimated ages at a initiations of the growth spurts in leg length and sitting height differ by only 0.1 and 0.2 years in the British boys and girls respectively, whereas ages at peak velocities differ by 0.7 and 0.6 years in these boys and girls, respectively. This suggests that the adolescent spurt in sitting height or trunk length occurs over a longer period of time than the spurt in leg length. Maximum growth is attained first by the tibia and the then the femur, followed by the fibula and then the bones of the upper extremity. Maximum growth in stature occurs, on the average, more or less at the same time as maximum growth of the humerus and radius. In early adolescent a youngster has relative long legs, because the bones of the lower extremity experience their growth spurts earlier than those of the upper extremity. With later growth in sitting height, the appearance of long-legdness disappears (Malina et al., 2004).

The lower extremity experiences its growth spurt before that of the trunk and upper extremity. Maximum velocities for lower limb dimensions precede PHV, whereas maximum velocities for body weight, sitting height, and skeletal breadths and circumferences of the trunk and upper extremities occur after PHV (Malina et al., 2004).

Age at PHV

Age at PHV is an indicator of maturation labeled as ‘‘non-invasive’’ and has been recently introduced in studies of young athletes (Malina et al., 2006; Mirwald, Baxter-Jones, Bailey, & Beunen, 2002; Sherar et al., 2007). Current age, height, sitting height, estimated leg length (height minus sitting height), weight, and interaction terms are used to estimate time before or after peak height velocity and in turn to predict age at peak height velocity (Mirwald et al., 2002).

Maturity Offset

Based on longitudinal data, the maturity offset method was developed to estimate the years from age at PHV (Mirwald et al., 2002). This predicted maturity offset age is quick, non-invasive to administer, and can be used in cross-sectional studies (Carvalho et al., 2012).

Predicted Mature Stature

Other somatic indicator is the estimation of percentage of adult stature attained and a prediction of adult height current height is expressed as a percentage of the predicted mature value. The rationale for the method is as follows: two youth of the same age can have the same height, but one is closer to mature height than the other. The youngster who is closer to mature height is advanced in maturity status compared with the one who is further from mature height (Bayer & Bayle, 1959; A. Roche, Tyleshevski, & Rogers, 1983).

Skeletal Age

The maturation of skeleton is widely recognized as the best single indicator of maturity status (Acheson, 1966). This maturity indicator focused on the examination of the development of bones of the hand and wrist, which generally reflect the remainder of the skeleton. Three methods for the assessment of skeletal maturity – the Greulich-Pyle (Greulich & Pyle, 1959), Tanner-Whitehouse (Malina, Chamorro, Serratosa, & Morate, 2007; Tanner, Healy, Goldstein, & Cameron, 2001) and Fells method (Roche, Chumlea, & Thissen, 1988) – are commonly used. Skeletal maturity is expressed as a skeletal age.

Longitudinal comparisons of studies in children and adolescents classified as active or athletes are limited (Beunen et al., 1992; Philippaerts et al., 2006), thus inferences about influence of growth and maturation on performance are largely based on cross-sectional data (Coelho-e-Silva, Figueiredo, Carvalho, & Malina, 2008; Mohamed et al., 2009). Physical performance is related to changes in the body size, composition and functional capacities that occur with biological maturation during adolescent. The relationship is more pronounced when boys of contrasting maturity status are compared. Boys who are advanced in biological maturity are generally better performers than their later maturing peers (Beunen & Malina, 1988) , and late-maturing boys appear to be excluded from many team sports (Figueiredo, Goncalves, Coelho, & Malina, 2009).

Previous research with youth participants in other team sports has also considered relationships among growth and maturity status and indicators of function and sport-specific skill. For example, among soccer players 11-14 years, skeletal maturation had a significant influence on body size, power (vertical jump), speed (repeated sprints) and aerobic capacity (endurance shuttle run), but did not influence soccer-specific skills (Figueiredo, Goncalves, Coelho-e-Silva, et al., 2009).

Among 12-to 13-year-old basketball players, height and adiposity had an inverse relationship with performances on manipulative-skill tests, while sport-specific skills were positively and linearly related to a combination of abdominal muscular strength reflected in 60-second sit-ups and aerobic endurance assessed with a 20-m shuttle run (Coelho-e-Silva et al., 2010) but still, there is a lack of studies on roller hockey.

Functional Fitness

Strength

There is data to suggest that training for football throughout youth and adolescence may lead to muscular development that is sport specific. Training for football may have a specific effect on muscular torque production in youths (Leatt, Shephard, & Plyley, 1987), especially in the knee extensor muscle group (Reilly, 2005). However there are no similar data for roller hockey.

Movement patterns in team-sports (e.g., basketball, soccer, and roller hockey), involve short, intense and repeated episodes of activity and rapid changes in direction, accelerations (Ares, 2005; Ben Abdelkrim, El Fazaa, & El Ati, 2007; Mohr, Krustrup, & Bangsbo, 2003) that require lower-limb muscle strength. Strength corresponds to maximal force generated (N) or moments of force ($N \cdot m^{-1}$) developed by a muscle or muscle group during maximal voluntary contraction under a given set of conditions (Sale, 1991).

Absolute maximal strength outputs increase with growth and maturation (G. Beunen & Malina, 1988) and are influenced by growth in body size and muscle mass (Geithner et al., 2004). It can be hypothesized that growth-related improvements in maximal strength outputs among young athletes are a function of increasing body size or qualitative changes in the structural and functional capacities independent of body size or both (Malina et al, 2004). Increments in maximal moment of force also depend upon neuromuscular maturation during adolescence (Housh et al., 1995) Howsoever, some studies said that this improvement with age requires a considerable increase in muscle power (Van Praagh & Dore, 2002), since not only are the individuals running faster or jumping higher but they also have to move a greater body mass (O'Brien, Reeves, Baltzopoulos, Jones, & Maganaris, 2009). This period of life is associated with the growth of skeletal muscle and, in boys, the additional development associated with the increase in circulating testosterone (Round, Jones, Honour, & Nevill, 1999).

Short–term power

It is well documented that performance of many high-intensity, short-duration anaerobic tasks, such as maximal running speed and jumping, improves throughout childhood and adolescence (Van Praagh, 1998; Van Praagh & Dore, 2002). The increase in strength during this time is most probably associated with increases in muscle fiber diameter and muscle cross-sectional area (O'Brien et al., 2009). Furthermore, Jones and Round (2000) point out that increases in muscle length during growth will also contribute to power, since the power of a muscle is determined by its volume, as the product of the mean cross-sectional area and length.

Aerobic Fitness

Aerobic fitness requires integration of pulmonary, cardiovascular, and hematological components of oxygen delivery and oxidative systems (Armstrong & Welsman, 2001; O'Brien et al., 2009). Training-induced changes in maximal oxygen uptake (VO_{2max}) are associated with improvements in the oxidative profile of skeletal muscle (Holloszy, (Holloszy, Rennie, Hickson, Conlee, & Hagberg, 1977). Body size and skeletal muscle are relevant factors in the interpretation of VO_{2max}. Maximal (relative) oxygen uptake is routinely expressed by unit of body mass as a ratio standard (e.g., $ml\cdot kg^{-1}\cdot min^{-1}$) although theoretical and statistical limitations of this approach have been noted. (Nevill, Ramsbottom & Williams, 1992a; Tanner 1949b)

About PHV and absolute VO_{2max}, it begins to increase about several years before PHV and continues to increase through the growth spurt. Relative VO_{2max} (ml O_2/kg/min) however can be improved by a induced-training increasing the oxidative profile of skeletal muscle (Holloszy et al., 1977), on the other hand relative VO_{2max} generally begins to decline a year or so prior to PHV and continues to decline for several years after PHV. The decline in relative maximal aerobic power reflects the rapid growth in body mass during the adolescent spurt, so that per unit body mass, oxygen uptake declines during growth spurt (Malina et al., 2004).

Allometric Scaling

Allometric models are effective for partitioning body-size effects in physiological variables or performances (Nevill et al., 1992a). Statistical models using linear regression and allometric scaling (log-linear regression) have been recommended to provide a "size-free" expression of VO_{2max} (Armstrong & Welsman, 1994; Nevill cooke, Holder, Ramsbottom & Williams, 1992).

Allometric models are an effective approach for partitioning the effects of body size and have been recommended as providing a 'size-free' expression of physiological parameters (Armstrong & Welsman, 2001; Nevill, Ramsbottom, et al., 1992b).

METHODS AND MATERIALS

Sample and procedures

During the peak of the 2008 junior roller hockey competitive season, 73 Caucasian male athletes, 14.5 to 16.5 years of age, from 15 clubs in Portugal, were enrolled in the study. The Portuguese Skating Federation, clubs, parents and athletes provided written consent.

At baseline, players were classified as juveniles (15-16 years) in the structure of *Fédération Internationale de Roller Sports* (F.I.R.H) youth hockey and as local (n=41) or international (n=32). The latter were selected for the national team. The distribution of players (local/international) by position was as follows: goalkeepers (6/7), defenders (16/13) and forwards (19/12). The distribution of players by position and competitive level did not differ ($\chi_{(2)}^2$=0.87, p=0.645). International players (15.4±0.4 years) competed with their respective clubs during the season and were included in the group of the Portuguese selections for the 2007 and 2008 U-17 European League. Local players (15.4±0.7 years) competed at the club level in the Aveiro, Coimbra and Leiria districts and in the metropolitan area of Oporto. The national team finished second in 2007 and first in 2008 in the U-17 European league.

All players participated in regular training sessions (2-5 sessions; 180-510 min.week^{-1}) with their clubs, and typically played one game per week. Clubs participated in a 9-month competitive season (September - May) through the Portuguese Skating Federation. Training sessions for the international group were irregularly scheduled during school holidays, specifically Carnival and Easter. European league competition usually occurred in September. For the international players, the national coach collected information about practice and game sessions, minutes of training and competition on a weekly basis and also years of training. Corresponding data for local players was obtained by assistant researchers (master's level students) who contacted the clubs and respective coaches on a weekly basis across the season.

This study was developed using recognized and standardized procedures all according with the Declaration of Helsinki. All data was collected under standard conditions in an indoor facility and biocinetic laboratory at the University of Coimbra. Specific details of the measurement and testing protocols are briefly described subsequently.

Age and Biological Maturation

Chronological age (CA) was calculated as the difference between date of birth and date of the hand-wrist radiograph. The posterior-anterior x-ray exams of the left hand-wrist were taken. All films were assessed by a single observer following the Fels method for skeletal age (SA) determination (Roche et al., 1998) . The protocol assigns grades to specific maturity indicators for the radius, ulna, carpals, metacarpals plus phalanges of the first, third and fifth rays (metacarpal and phalanges) and utilizes ratios of linear measurements of the widths of the epiphysis and metaphysis of the long bones. The presence (ossification) or absence of the pisiform and adductor sesamoid is also rated. Grades and ratios are entered into a program (Felshw 1.0 Software, Lifespan Health Research Center, Departments of Community Health and Pediatrics, Boonshoft School of Medicine, Wright State University, Dayton, Ohio) to derive a S.A. The statistical protocol weighs the contributions of specific indicators, depending on CA and sex, in calculating a SA and its standard error of estimate (a confidence interval for the assessment). The standard error is a unique feature of this protocol. Standard errors slightly increased with age (11–12 years: 0.27–0.32; 13–14 years: 0.27–0.49; 15–17 years: 0.28–0.72) because at older ages the assessment is based on less indicators (Malina et al., 2010; Roche et al., 1988).

Twenty radiographs were independently assessed by the single observer who was trained by an experienced assessor. The mean difference between SA assessments of the two observers and the inter-observer technical error of measurement were small, respectively 0.03 0.99 years. The total number of indicators involved in the assessment of the 20 films was 988 and disagreement between assessors occurred on 48 occasions (all disagreements were by one grade or by 0.5 mm for metaphyseal and epiphyseal widths).

Midparent stature were used to predict mature (adult) stature for the boys using the Khamis–Roche protocol (Khamis & Roche, 1994). The median error bound (median absolute deviation) between actual and predicted mature stature at 18 years of age is 2.2 cm in males (Khamis & Roche, 1994). Current stature of each player was expressed as a percentage of his predicted mature stature to provide an estimate of biological maturity status. Percentage of mature stature attained at a given age is positively related to skeletal maturity during childhood and to sexual, skeletal, and somatic maturity during adolescence (Malina, et al., 2004).

Age at PHV was estimated with the maturity offset protocol (Mirwald et al., 2002). The technique estimates time before or after PHV using a sex-specific equation that incorporates chronological age, stature, body mass, sitting height and estimated leg length (stature minus sitting height). Negative offset values indicated time before PHV and positive values indicated time after PHV. Negative offset values were added to and positive offset values were subtracted from chronological age to estimate age at PHV.

Anthropometry

Stature, sitting stature, arm span, body mass, and two skinfolds (triceps and subscapular) and arm span were measured by single, experienced individual following standard procedures. (Lohman, Roche, & Martorell, 1988) Stature, sitting stature and arm span were measured to the nearest 0.1 m with a Harpenden stadiometer (model 98.603, Holtain Ltd, Crosswell, UK), with a Harpenden sitting height table (Holtain Ltd, Crosswell, UK) and with a Telescopic stadiometer (Model Health – Nutrition - GLXY), respectively. Leg (subischial) length was estimated as height minus sitting height. The sitting height/standing height ratio was calculated. Body mass was measured to the nearest 0.1 kg with a SECA balance (model 770, Hanover, MD, USA). Skinfolds were measured to the nearest mm using a Lange Caliper (Beta Technology, Ann Arbor, MI, USA). Technical errors of measurement (TEM) for stature (0.27 cm), sitting stature (0.31 cm), arm spam (0.29 cm), body mass (0.47 kg), and skinfolds (0.47-0.72 mm) were well within the range of several health surveys in the United States and a variety of field surveys (Malina et al. 2004). Fat mass was estimated from triceps and subscapular skinfold thicknesses using the protocol of Slaughter and colleagues (Slaughter et al., 1988). Fat-free mass was derived in kg.

Field Tests

Squat and Counter Movement Jump

Explosive power of lower limbs was assessed with the vertical jump using the ergo-jump protocol, which includes two components: Squat jump (SJ) and counter-movement jump (CMJ) (Bosco, 1994). Two trials were administered for each test and the better trial was retained for analysis.

Standing Long Jump

To evaluate the muscular power of lower limbs a standing long jump was performed. In this test it is supposed to achieve the most distant point on the horizontal plane. In this test it is supposed to achieve the most distant point on the horizontal plane. The same protocol was also used on other studies (Coelho-e-Silva et al., 2008).

Sit-Ups

To assess the middle strength a 60 sec sit-ups test was performed. The players were lying down, on a dorsal position with tied feet and knee flection. The upper limbs were crossed upon the chest. One repetition was counted when cycle begins with a contact of the trunk on the floor and ends with the elbows reach the knees (Coelho-e-Silva et al., 2008; Mohamed et al., 2009).

Hand-Grip

Static grip strength was assessed with an adjustable dynamometer (Lafayette model, Lafayette, IN, USA). The procedure of the test is explained on a battery of tests designed by FACDEX project (Sobral, 1992).

2-Kg Ball Throw

The athlete in a standing position, holds the medicinal ball with both hands, puts it behind the head, and without taking the feet of the floor, throws the ball as far as he could, trying to achieve the best mark. Other studies also used the same protocol (Coelho-e-Silva et al., 2008).

25m dash

Running speed was measured with a 25-m dash running. Two trials were administered and the best was retained for analysis. Time was measured with photoelectric cells (Globus Ergo Timer Timing System, Codogné, Italy).

PACER

Aerobic performance was measured with the 20-m multi-stage continuous shuttle endurance test (Leger, Mercier, Gadoury, & Lambert, 1988), a standard field test included in the European fitness test battery (EUROFIT, 1988) and in the Portuguese physical education curriculum. In brief, 5–10 athletes performed a series of runs across a 20m track, changing direction at the end of each run to coincide with an audio signal that was getting progressively faster. Subjects started running at a speed of 8.5 km·h– 1, and speed increased at various stages (0.5 km·h– 1 every minute). Each stage was made up of several shuttle runs, and subjects were instructed to keep pace with the signals as long as possible. The results were recorded as laps taken to complete the 20m shuttle-run test. Aerobic performance was expressed as the number of completed laps achieved in the shuttle run test, as done previously.

Technical Errors of Measurement and Reliability Coefficients for Field Tests

Subjects were familiar with the respective protocols because the tests are included in the physical Education Curriculum of the Portuguese schools. Based on a test-retest protocol (one week apart), technical errors of measurement (σ_e) and reliability coeficients (R) were determined (Mueller & Martorell, 1988): squat jump (n = 21): σ_e = 1.9 cm, R = 0.82; counter movement jump (n = 21): σ_e = 1.7 cm, R = 0.88; standing long jump (n = 21): σ_e = 0.06, R = 0.91; sit-ups (21): σ_e = 3.3 cm, R = 0.84; hand grip (21): σ_e 0.9 Kg, R = 0.99; 2-Kg ball throw (21): σ_e = 0.045 s, R = 0.92; 25 m dash (n = 35): σ_e = 25, R 0.98; PACER (n = 32): σ_e = 20 m, R = 0.86.

Laboratory Tests

Assessment of Aerobic Fitness

Peak VO2 was determined using an incremental running test on a motorized treadmill (Quasar, HP Cosmos, Germany). Participants started with 2 minutes at 8 km/h with subsequent increments of 2 km/h every minute until 16 km/h. Exercise intensity was subsequently increased through increasing the treadmill grade by 2^{nd} every minute until exhaustion (Lawrence & Polglaze, 2000). Criteria for attainment of peak VO2 were: respiratory exchange ratio (RER) ≥ 1.00 and heart rate (HR) within 5% of the age predicted maximum (Armstrong & Welsman, 2001). Expired oxygen (O2) and carbon dioxide (CO2) flow and concentrations were measured every 10 seconds using a mixing chamber system (MetaMax System, Cortex Biophysics, Leipzig, Germany).

Calibration and ambient air measurements were conducted before each testing session according to the manufacturer's guidelines. Before each test, flow and volume were calibrated using a 3-L capacity syringe (Hans Rudolph, Kansas City, USA). Gas analysers were calibrated using gases of known concentrations. HR was measured throughout exercise with a commercially available HR-monitor (Polar Electro, Finland).

Wingate Test (Assessment of Anaerobic Power)

After a standardized warm-up, athletes completed the 30-s Wingate test (WAnT) on a friction-loaded cycle ergometer (Monark 824E, Monark AB, Vargerg, Sweden) that was interfaced with a microcomputer and calibrated for pedal speed and applied resistance that was set at 0.075 kg (0.74 N) per unit of body mass. The WAnT test began with minimal resistance (basket supported) at 60 rep·min^{-1}. On the command “go”, the resistance was abruptly applied and the computer was simultaneously activated. To measure flywheel velocity, an optical sensor counted pulses using 16 markers that were mounted on the side of the flywheel in front of the sensor (Opto Sensor 2000, Sports Medicine Industries Inc, St. Cloud, MN). Peak and mean outputs were calculated by averaging the five consecutive seconds. Test outputs included peak output (P-WAnT, highest generated mechanical output in watt), mean output (M-WAnT, average for the 30-s period, watt) and a fatigue index (FI-WAnT), which corresponds to the peak output minus lowest output divided by peak (Inbar, Bar-Or, & Skinner, 1996). Coefficients of variation based on replicate tests in 20 subjects were 2.8%, 3.2% and 8.7% for P-WAnT, M-WAnT and FI-WAnT, respectively (Carvalho et al., 2010).

Isokinetic evaluation

Isokinetic concentric and eccentric knee extension and flexion were measured using a calibrated dynamometer (Biodex System 3, Shirley, NY, USA) at angular velocities of 60º.s-1 after a 10-min warm-up on a cycle ergometer (Monark 814E, Varberg, Sweden) with minimal resistance (basket supported) at 60 rev.min-1 and 2 min of static stretching of the hamstring and quadriceps muscles. Participants were in a seated position in a standardized 85º hip flexion from the anatomical position. Range of motion was set using voluntary maximal full knee extension (0º) to knee flexion (90º). Cushioning was set using a hard deceleration (according to manufacturer guidelines) and therefore 90º constituted the range of motion tested. In the concentric action, the participant was instructed to push the arm lever during extension and pull during flexion as hard and fast as possible. In the eccentric action, the subject was instructed to resist the lever arm during extension and flexion as hard as possible. Each subject performed five continuous maximal repetitions on each mode and leg. Visual feedback of moment versus time was provided during the test, but no verbal feedback was given (Baltzopoulos, Williams, & Brodie, 1991). Isokinetic assessments were completed within a one week period that included a familiarization and testing sessions with at least 48-h between sessions; intra-observer reliability estimates (coefficient of variation) for the tested muscular actions ranged from 3.9 to 6.0% (Carvalho, Coelho, Ronque, et al., 2011). Maximal knee flexion and extension peak torque of the best repetition in both concentric and eccentric muscular actions were retained and expressed as Nm. Eccentric knee extension (ECCKE) divided by concentric knee extension (CCKE) peak torques (ECCKE/CCKE), and concentric knee flexion (CCNKF) divided by eccentric knee flexion (ECCKF) peak torques were calculated as a predictor of the thigh musculature stability (Aagaard, Simonsen, Magnusson, Larsson, & Dyhre-Poulsen, 1998).

The reliability for replicate tests within one week, for the isokinetic evaluation, was determined on a year basis using 13 athletes which were university students. Reliability coefficients (R) and coefficients of variation (CV) were calculated as outlined by Hopkins (2000): KECON: R = 0.98, CV = 7.1%; KFCON: R = 0.98, CV = 4%; KEECC: R = 0.97, CV = 8.4%; KFECC: R = 0.97, CV = 12.5.

Statistical Analyses

Descriptive statistics were calculated for the total sample (minimum, maximum, mean and standard deviation) and Kolmogorov-Smirnov tests used to check normality. Pearson correlation coefficients were calculated between body mass and functional tests. The corresponding strength was assessed using Pearson's correlation coefficient (r). The following criteria were adopted for interpreting the magnitude of correlation (r) between test measures: Coefficients were interpreted as follows: trivial ($r < 0.1$), small ($0.1 < r < 0.3$) moderate ($0.3 < r > 0.5$), large ($0.5 < r < 0.7$), very large ($0.7 < r < 0.9$), nearly perfect ($r > 0.9$) and perfect ($r = 1$) (Hopkins, Marshall, Batterham, & Hanin, 2009).

Allometric equations, $Y=a\cdot X^{b}\cdot\varepsilon$, where a is the intercept of the regression line on the Y-axis and b is the slope of the line, were used to model the relationship between functional variables and body size. Values of a and b were derived from linear regressions of the logarithmic regression transformations, in the form of log $Y=loga+b\cdot logx+log\mathcal{E}$, where Y was the dependent variable (e.g., maximal oxygen uptake) of functional tests measures (log-transformed) and body size descriptor (log body mass). Regression diagnostics (Nevill et al., 1992b), were performed to check whether the allometric models were successful in partitioning out the influence of body size on the functional tests. All models resulted in size-independent scores of the functional tests (data not shown). The size-adjusted measurements were subsequently considered in comparisons of players by position. Factorial ANOVA was used to compare the variation by playing position on CA, SA, training experience, anthropometric characteristics, and field and laboratory tests. The effect size correlations (ES-*r*) were estimated using the square root of the ratio of the F value squared and the difference between the F value squared and degrees of freedom (Rosnow & Rosenthal, 1996). Using those variables that were significantly influenced by player position, discriminant function analysis was used to obtain a predictive model that permitted classification of hockey players as attackers or defenders, i.e., the original groupings. It was possible to order the predictors by the magnitude of correlations with the linear function. Subsequently, a stepwise model was used to test the hypothesis of extracting an alternative predictive model based on a smaller set of variables without losing explained variance. Percentages of players who were correctly classified based on the discriminant linear functions were noted. Significance level was set at 5%. Analyses were performed using SPSS version 17.0 software (SPSS,Chicago, IL).

RESULTS

Descriptive statistics for the total sample are summarized in tables 1, 2 and 3. Training experience ranged six years (5 to 11 years). Substantial differences between minimum and maximum values were also noted for the number of training and playing sessions, respectively 95 (66 to 161 sessions) and 46 (11 to 57 games). By influence the range of the above mentioned variables in minutes were also substantial: 8155 minutes for training and 1956 minutes for playing.

Table 1. Descriptive statistics of male adolescent roller hockey players (n=73) on training parameters, chronological age, maturation and anthropometry.

Variable	Range		Mean ± St Dev	Kolmogorov – Smirnov	
	min	*Max*		Value	*P*
Training experience, years	5	11	8.6 ± 1.2	1.540	0.017
Training sessions, n	66	161	111 ± 16	0.819	0.514
Training time, min	5980	14135	9427 ± 1282	0.784	0.571
Playing games, n	11	57	33.8 ± 7.8	0.914	0.374
Playing time, min	147	2103	827 ± 341	0.914	0.552
Chronological age (CA), years	13.53	16.77	15.41 ± 0.64	3.880	0.000
skeletal age (SA), years *	13.10	18.00	16.41 ± 1.47	3.746	0.000
Predicted mature stature, cm	158.2	185.6	174.4 ± 5.4	2.898	0.000
Predicted mature stature, %	90.8	99.9	97.4 ± 2.0	3.077	0.000
Maturity offset, years	-1.19	2.98	1.45 ± 0.84	4.030	0.000
Age at PHV, years	12.57	15.67	13.96 ± 0.67	3.736	0.000
Stature, cm	143.6	182.2	169.9 ± 6.9	2.732	0.000
Body mass, kg	38.4	98.6	63.9 ± 11.3	0.829	0.498
Sitting height, cm	75.4	96.6	89.3 ± 4.6	2.096	0.000
Leg length, cm	68.2	87.1	80.6 ± 3.8	2.422	0.000
Sitting height – height, ratio	49.2	57.4	52.6 ± 1.4	2.979	0.000
Arm span, cm	149.3	194.5	177.2 ± 8.4	2.342	0.000
Fat mass (FM), kg	3.2	30.8	11.8 ± 6.2	1.712	0.006
Fat free mass (FFM), kg	34.2	68.7	52.1 ± 7.9	0.677	0.749

(*) 16 players were already skeletally mature and their skeletal age was not considered

The sample of the current study demonstrated more variability in skeletal age (16.41 ± 1.47 years) than in chronological age (15.41 ± 0.64 years). Estimate of the peak height velocity ranged from 12.57 to 15.57 years with a mean value of 13.96 years. Note that a negative value in the maturity offset means that participants were not PHV, while positive value in intercepted as assessment after PHV.

Regarding morphological variables, the sample comprised a large inter-individual variability which is visible in stature (ranged 38.6 cm) and body mass (ranged 50.2 Kg).

Table 2. Descriptive statistics of male adolescent roller hockey players (n=73) for field performance tests.

Variable	Range		Mean ± St Dev	Kolmogorov – Smirnov	
	min	*Max*		Value	*p*
Squat jump, cm	19.2	40.3	30.7 ± 5.1	0.586	0.882
Countermovement jump, cm	20.1	57.0	32.9 ± 5.9	1.437	0.032
Standing Long Jump, cm	168	238	196 ± 19	4.509	0.000
Sit-ups, repetitions	22	46	29.1 ± 4.4	1.526	0.019
Hand grip strength test, kg	23	57	39.5 ± 8.2	0.829	0.498
2-Kg ball throw, m	5.13	11.30	7.48 ± 11.41	3.063	0.000
25-m dash, s	3.62	4.82	4.06 ± 0.27	4.338	0.000
25-m dash with skates, s	3.72	5.31	4.23 ± 0.28	4.192	0.000
25-m dash with skates and stick, s	3.87	5.33	4.40 ± 0.30	4.258	0.000
20-m shuttle run, m	1020	2460	1627 ± 324	0.710	0.695

The test for checking the normality noted the violation of the assumption in several variables at all domains (maturation, anthropometry, field performance and laboratorial outputs).

Table 3. Descriptive statistics of male adolescent roller hockey players (n=73) on laboratory protocols.

Variable	Range		Mean ± St Dev	Kolmogorov – Smirnov	
	min	*Max*		Value	*p*
Peak oxygen uptake, L·min^{-1}	2.48	5.46	3.89 ± 0.62	3.978	0.000
WAnT: peak output, watt	269	913	595.8 ± 129.1	0.879	0.423
WAnT: mean output, watt	238	747	506.2 ± 99.2	1.329	0.058
WAnT: fatigue index	11.0	49.7	30.7 ± 7.3	0.890	0.406
Peak Torque KE_{CC}, Nm	110.5	297.6	176.9 ± 36.1	1.005	0.264
Peak Torque KF_{ECC}, Nm	114.7	432.4	245.4 ± 69.5	0.670	0.760
Peak Torque KF_{CC}, Nm	58.4	161.0	102.6 ± 21.4	0.623	0.832
Peak Torque KE_{Ecc}, Nm	85.8	256.8	152.5 ± 34.5	4.424	0.000

Table 4 presents the bivariate correlations between performance tests and body size descriptors. When the correlation considered body mass it was possible to identify a unique large association with hand grip strength (r = + 0.639, p < 0.001). The static strength with the hand grip dynamometer were also correlated over 0.50 with fat free mass (r = + 0.830; p < 0.001) which was also largely correlated with the 2-Kg ball throw (*r* = + 0.579; *p* < 0.001). No substantial differences were noted between lower limb value and field performance tests.

Table 4. Bivariate correlation between size descriptors and field performance test outputs in male adolescent roller hockey players (n=73).

Field performance (Y_i)	Body mass (x_1)		Fat free mass (x_2)	
	r	*P*	*r*	*p*
Squat jump	-0.185	0.116	-0.035	0.768
Countermovement jump	0.085	0.476	0.040	0.735
Standing Long Jump	0.071	0.550	0.234	0.047
Sit-ups, repetitions	-0.009	0.937	-0.018	0.878
Hand grip strength	0.639	0.000	0.830	0.000
2 Kg ball throw	0.453	0.000	0.579	0.000
25m dash,	0.078	0.512	0.074	0.536
25m dash with skates	0.147	0.214	0.107	0.367
25m dash with skates and stick	0.150	0.206	0.176	0.136
20m Shuttle run	-0.084	0.481	0.145	0.221

Due to the interrelationship between body mass and particular aspects of motor performance tests, it was decided to obtain allometric exponents to control the spurious effect of body size on performance. The allometric coefficients were 0.639 and 0.453 respectively for hand grip strength and 2-Kg ball throw. These exponents allow the application of the following outputs hand grip expressed in $\mathrm{Kg}\cdot\mathrm{Kg}_{BM}\cdot^{-0.639}$ and 2-Kg ball trhow expressed in $\mathrm{m}\cdot\mathrm{Kg}_{BM}\cdot^{-0.453}$. It was also tried to obtain simple allometric models for fat free mass but they failed to remove the spurious effect associated with size (data not showed).

Table 5. Exponent obtained from log-transformed allometric models ($Y=a.X^b+\varepsilon$)[1] for performance field tests that were largely correlated with body size (left portion of the table); and bivariate correlation between size descriptors (X_i) and scaled performance on field tests ($Y_i.X_i^{-b}$) in male adolescent roller hockey players (n=73).

Field performance (Y_i)	Body Mass (x_i)		
	allometric exponent	*r* ($Xi, Yi\cdot xi^{-b}$)	*P*
Hand grip strength	0.639	-0.018	0.96
2 Kg ball throw	0.453	+0.016	0.88

[1] i.e. Log Y_i= Log a + b . Log X_i + Log ε

Bivariate correlations were also performed between size descriptors and laboratory protocol outputs and several large coefficients were found:

-With body mass: peak oxygen uptake (r = +0.604, $p \leq 0.001$), WAnT – peak output (r = 0.952; $p \leq 0.001$), WAnT – mean output (r = 0.892; $p \leq 0.001$), peak torque of knee extension in the concentric mode (r = 0.588; $p \leq 0.001$) and peak torque of knee flection in the eccentric mode (r = 0.567; $p \leq 0.001$).

-With fat-free mass the same variables that were correlated with body mass were largely correlated with negligible differences in the magnitude of the coefficient.

However, value estimated for the leg lean volume was used as size descriptor, all outputs were largely correlated with the exception of the fatigue index emerged from the Wingate protocol. Specific coefficient were detailed presented in table 6 (right position) and the magnitude of peak torque did not substantially vary between knee extension and knee flexion on the concentric and eccentric modes.

Table 6. Bivariate correlation between size descriptors and laboratory protocol outputs in male adolescent roller hockey players (n=73).

Laboratory protocol outputs (Y_i)	Body Mass (x_1)		Fat Free Mass (x_2)	
	r	*p*	*r*	*p*
Peak oxygen uptake	0.604	0.000	0.576	0.000
WAnT: peak output	0.952	0.000	0.956	0.000
WAnT: mean output	0.892	0.000	0.902	0.000
WAnT: fatigue index	-0.028	0.813	-0.082	0.491
Peak Torque KE_{CC}	0.588	0.000	0.626	0.000
Peak Torque KF_{ECC}	0.567	0.002	0.579	0.005
Peak Torque KF_{CC}	0.478	0.000	0.498	0.001
Peak Torque KE_{ECC}	0.386	0.008	0.278	0.094

In order to obtained allometric exponents for the same size descriptor used for field performance tests, it was decided to produce models uniformly from body mass and this allows the following expression $mL\cdot Kg_{BM}\cdot^{-0.600}{}_{min}$ for peak oxygen uptake, $W\cdot Kg_{BM}{}^{-0.952}$ for WAnT – peak, $W\cdot Kg_{BM}{}^{-0.892}$ for WAnT – mean, $N.m\cdot Kg_{BM}{}^{-0.588}$ for the peak torque of the knee extension (concentric mode), $N.m\cdot Kg_{BM}{}^{-0.57}$ for the peak torque of knee flexion (eccentric mode), $N.m\cdot Kg_{BM}{}^{-0.478}$ for the peak torque on knee flexion (concentric mode) and $N.m\cdot Kg_{BM}{}^{-0.386}$ for the peak torque on knee extension (eccentric mode).

Table 7. Exponent obtained from log-transformed allometric models ($Y=a.X^b+\varepsilon$)[1] for laboratory protocol outputs that were largely correlated with body size (left portion of the table); and bivariate correlation between size descriptors (X_i) and scaled outputs derived from laboratory protocols ($Y_i.X_i^{-b}$) in male adolescent roller hockey players (n=73).

Laboratory protocol outputs (Y_i)	Body Mass (x_1)		
	allometric exponent	*r* (Xi, $Yi \cdot xi^{-b}$)	*p*
Peak oxygen uptake	0.600	-0.013	0.91
WAnT: peak output	0.952	-0.054	0.66
WAnT: mean output	0.892	-0.055	0.66
Peak Torque KE_{CC}	0.598	0.011	0.94
Peak Torque KF_{ECC}	0.570	0.039	0.76
Peak Torque KF_{CC}	0.478	0.029	0.82
Peak Torque KE_{ECC}	0.386	0.065	0.61

[1] i.e. $\text{Log } Y_i = \text{Log } a + b \,.\, \text{Log } X_i + \text{Log } \varepsilon$; [2] not significant

Tables 8 and 9 present the descriptive statistics of sport experience, not mention and anthropometry by playing position and it was possible to observe a significant effect on body mass (F = 6.076; *p* = 0.004; ES-*r* = 0.385) and fat-mass (F = 5.913; *p* = 0.004; ES-*r* = 0.380).

Table 8. ANOVA to test the effect of playing position (attackers, n=31; defenders, n=29; goalkeepers, n=13), on training parameters.

Variable	Goalkeepers M±SD	Defenders M±SD	Attackers M±SD	F	*p*	Es-*r*
Training experience, years	8.3 ± 1.4	8.9 ± 1.2	8.5 ± 1.1	1.345	0.267	0.019
Training sessions, n	110 ± 15	111 ± 18	110 ± 15	0.041	0.960	0.001
Training time, min	9255 ± 1299	9421 ± 1352	9506 ± 1243	0.172	0.843	0.002
Playing games, n	34 ± 8	33 ± 7	34 ± 9	0.160	0.853	0.002
Playing time, min	909 ± 439	791 ± 304	825 ± 336	0.529	0.592	0.007

Particular post-hoc tests noted the following differences between goal-keepers and defenders:

-body mass (mean difference = 10.69; *p* = 0.011);

-fat mass (mean difference = 6.21; *p* = 0.007);

And between goalkeepers and attackers differences were statically significant for the following dependent variables:

-body mass (mean difference = 11.78; *p* = 0.004);

-fat mass (mean difference = 6.12; $p = 0.007$);

However there were no differences between attackers and defenders for chronological age, maturation and anthropometry variables.

Table. 9 ANOVA to test the effect of playing position (attackers, n=31; defenders, n=29; goalkeepers, n=13), on chronological age, maturation and anthropometry.

Variable	Goalkeepers M±SD	Defenders M±SD	Attackers M±SD	F	*P*	Es-*r*
Chronological age (CA), years	15.5 ± 0.5	15.4 ± 0.7	15.4 ± 0.6	0.263	0.769	0.086
skeletal age (SA), years *	16.9 ± 1.02	16.3 ± 1.6	16.3 ± 1.5	0.963	0.387	0.164
Predicted mature stature, cm	175.5 ± 5.2	174.5 ± 6.2	173.8 ± 4.9	0.424	0.656	0.109
Predicted mature stature, %	98.0 ± 1.2	97.4 ± 2.5	97.3 ± 1.9	0.566	0.570	0.126
Maturity offset, years	1.83 ± 0.54	1.47 ± 0.96	1.26 ± 0.78	2.199	0.119	0.243
Age at PHV, years	13.69 ± 0.48	13.83 ± 0.71	14.15 ± 0.65	2.576	0.083	0.262
Stature, cm	171.9 ± 5.4	169.928 ± 8.3	169.1 ± 5.9	0.777	0.464	0.147
Body mass, kg	73.2 ± 11.1	62.5 ± 10.9	61.4 ± 10.2	6.076	0.004	0.385
Sitting height, cm	91 ± 2.7	89.8 ± 5.3	88.2 ± 4.3	1.996	0.144	0.232
Leg length, cm	81 ± 3.8	80.1 ± 4.1	80.9 ± 3.6	0.390	0.678	0.105
Sitting height – Height, ratio	52.9 ± 1.2	52.8 ± 1.3	52.1 ± 1.6	2.278	0.110	0.247
Arm span, cm	181 ± 9.0	177.6 ± 7.7	175.3 ± 8.4	2.369	0.101	0.252
Fat mass (FM), Kg	16.9 ± 8.9	10.7 ± 5.6	10.8 ± 4.4	5.913	0.004	0.380
Fat free Mass (FFM), Kg	56.3 ± 6.3	51.8 ± 8.7	50.6 ± 7.4	2.466	0.092	0.257

(*) 16 players were already skeletally mature and their skeletal age was not considered.

Table 10 corresponds to the statistics of comparison between playing positions for the field performance tests. Differences were repeated for the item that claimed allometric models and this was justified by the significant inter-relationship between playing position and body mass.

Difference between goalkeepers, defenders and attackers were significant for the majority of items that required displacement of the total body mass: squat jump (F = 4.736; Es-$r = 0.345$; $p = 0.012$), countermovement jump (F = 3.851; Es-$r = 0.315$; $p = 0.026$), 25m dash (F = 5.848; Es-$r = 0.378$; $p = 0.004$), 25m dash skating (F = 7.443; Es-$r = 0.419$; $p = 0.001$), 25m dash skating and with stick (F = 12.171; Es-$r = 0.508$; $p = 0.000$), and also the PACER (F = 3.565; Es-$r = 0.304$; $p = 0.034$). No differences were found for the other tests that did not require overall body displacement nor for the scaled outputs of the hand grip and 2-Kg ball throw.

Particular post-hoc tests noted the following differences between goalkeepers and defenders:

-25m dash (mean difference = 0.19; *p* = 0.093);
-25m dash skating (mean difference = 0.28; *p* = 0.005);
-25m dash skating with stick (mean difference = 60.28; *p* = 0.005);
- PACER (mean difference = 261.99; *p* = 0.040);

And between goalkeepers and attackers differences were statically significant for the following dependent variables:

-Squat jump (mean difference = 4.68; *p* = 0.013);
-Countermovement jump (mean difference = 5.19; *p* = 0.022);
-25m dash (mean difference = 0.28; *p* = 0.03);
-25m dash skating (mean difference = 0.32; *p* = 0.001);
-25m dash skating with stick (mean difference = 0.41; *p* = 0.000);

Finally, post hoc comparison shows us that there were no differences between defenders and attackers on field performance tests.

Table 10. ANOVA to test the effect of playing position (attackers, n=31; defenders, n=29; goalkeepers, n=13) on field performance tests.

Variable	Goalkeepers M±SD	Defenders M±SD	Attackers M±SD	F	*p*	Es-*r*
Squat jump, cm	27.8 ± 4.8	30.0 ± 5.3	32.5 ± 4.3	4.736	0.012	0.345
Countermovement jump, cm	29.4 ± 5.1	32.7 ± 4.7	34.6 ± 6.6	3.851	0.026	0.315
Standing Long Jump, cm	1.9 ± 0.2	2.0 ± 0.2	2.0 ± 0.2	1.603	0.209	0.209
Sit-ups, repetitions	29.2 ± 3.2	29.3 ± 4.1	28.8 ± 5.2	0.106	0.900	0.055
Hand grip strength test, kg	40.2 ± 7.4	40.1 ± 8.3	38.6 ± 8.4	0.286	0.752	0.090
Hand grip, $\mathrm{Kg} \cdot \mathrm{Kg}_{BM}^{-0.639}$	2.6 ± 0.5	2.9 ± 0.4	2.8 ± 0.5	1.185	0.312	0.181
2-Kg ball throw, m	8.04 ± 1.86	7.51 ± 1.39	7.21 ± 1.16	1.653	0.199	0.212
2-Kg ball throw, $\mathrm{m} \cdot \mathrm{Kg}_{BM}^{-0.453}$	1.15 ± 0.25	1.16 ± 0.18	1.12 ± 0.18	0.265	0.768	0.087
25-m dash, s	4.25 ± 0.0.97	4.07 ± 0.26	3.97 ± 0.18	5.848	0.004	0.378
25-m dash with skates, s	4.48 ± 0.40	4.19 ± 0.26	4.15 ± 0.18	7.443	0.001	0.419
25-m dash with skates and stick, s	4.72 ± 0.36	4.36 ± 0.26	4.30 ± 0.21	12.171	0.000	0.508
20-m shuttle run, m	1468 ± 323	1590 ± 296	1730 ± 323	3.565	0.034	0.304

Regarding laboratory protocol outputs, table 11 presents the comparison between playing positions for peak oxygen uptake. No differences were found when the dependent variable was expressed in absolute values, that is, in $\mathrm{L \cdot min^{-1}}$. However, when the variable is expressed in $\mathrm{mL \cdot Kg \cdot min^{-1}}$ the effect of playing position is statistically significant (F = 3.377, *p* = 0.040, Es-*r* = 0.297) with post hoc comparison showing that goalkeepers attained poorer performances than defenders (mean difference = 7.38, *p* = 0.037). There were no differences among goalkeepers and attacker or among defenders and attackers.

Table 11. Allometric Modeling and ANOVA to test the effect of playing position (attackers, n=31; defenders, n=29; goalkeepers, n=13) on aerobic fitness.

Variable	Goalkeepers M±SD	Defenders M±SD	Attackers M±SD	F	*p*	Es-*r*
Peak oxygen uptake, L.min^{-1}	4.07 ± 0.51	3.94 ± 0.75	3.76 ± 0.51	1.258	0.291	0.186
Peak oxygen uptake, mL · kg$_{BM}$ · min^{-1}	56.14 ± 7.33	63.52 ± 10.13	62.00 ± 7.44	3.377	0.040	0.297
Peak oxygen uptake, mL · kg$_{BM}^{-0.60}$ · min^{-1}	310.68 ± 32.48	329.68 ± 48.37	319.46 ± 32.07	1.148	0.323	0.178

Table 12 evidenced the profile of goalkeepers, defenders and attackers in the outputs derived from the Wingate test (WAnT) and the peak torques obtained from the isokinetic tests. It was possible to note a significant difference between playing position uniformly for the peak output (F = 3.204, *p* = 0.047, ES-*r* = 0.290), among the several variables obtained for the WAnT. Note that this occurred for the peak output informed by its absolute format, in watts. After obtaining the relative formats in Watts·Kg$^{-0.952}$, the group did not statistically differ. The post hoc comparison noted that mean differences (101.47) were only significant (*p* = 0.04) between goal keepers and attackers.

Table 12. Allometric Modeling and ANOVA to test the effect of playing position (attackers, n=31; defenders, n=29; goalkeepers, n=13) on Wingate test.

Variable	Goalkeepers M±SD	Defenders M±SD	Attackers M±SD	F	*P*	Es-*r*
WAnT: peak output, watt	659.7 ± 97.2	607.3 ± 151.1	558.2 ± 107.6	3.204	0.047	0.290
WAnT: peak output, watt · kg$_{BM}$	9.1 ± 0.9	9.7 ± 2.0	9.1 ± 1.2	1.432	0.246	0.198
WAnT: peak output, watt · Kg$_{BM}^{-0.952}$	11.1 ± 1.1	11.8 ± 2.4	11.1 ± 1.4	1.374	0.260	0.194
WAnT: mean output, watt	552.9 ± 70.1	511.7 ± 117.8	481.6 ± 84.3	2.544	0.086	0.260
WAnT: mean output, watt · Kg$_{BM}$	7.6 ± 0.7	8.2 ± 1.4	7.9 ± 0.9	1.294	0.281	0.189
WAnT: mean output, watt · Kg$_{BM}^{0.892}$	12.1 ± 1.0	12.8 ± 2.2	12.3 ± 1.4	0.976	0.382	0.165
WAnT: fatigue index	31.7 ± 5.9	31.4 ± 8.0	29.7 ± 7.2	0.533	0.589	0.122

Among variables presented in table 13 that includes the concentric and eccentric mode of knee extension and knee flexion. Each output was expressed in N·m, N·m·kg^{-1} and N·m·kg^{-b} (b corresponds to allometric exponent). Significant differences between playing positions were noted for the eccentric mode of knee flection in N·m·kg^{-1} (F = 4.077, *p* = 0.021, ES-*r* = 0.323) with goalkeepers (3.2 ± 1.0) attaining poorer score than defenders (3.9 ± 1.2) and attackers (4.1 ± 0.8), post hoc comparison noted that mean differences (0.91) were only significant (*p* = 0.019) between goal keepers and attackers.

Table 13. Allometric Modeling and ANOVA to test the effect of playing position (attackers, n=31; defenders, n=29; goalkeepers, n=13) in isokinetic assessments.

Variable	Goalkeepers M±SD	Defenders M±SD	Attackers M±SD	F	*p*	Es-*r*
Peak Torque KE_{CC}, N.m	185.6 ± 43.6	179.7 ± 31.0	170.6 ± 37.2	0.935	0.398	0.161
Peak Torque KE_{CC}, N.m · kg_{BM}	2.5 ± 0.5	2.9 ± 0.6	2.6 ± 0.5	2.476	0.091	0.257
Peak Torque KE_{CC}, N.m · $kg_{BM}^{-0.588}$	14.9 ± 2.9	15.9 ± 2.4	15.2 ± 2.7	0.914	0.406	0.160
Peak Torque KF_{ECC}, N.m	236.6 ± 86.7	242.9 ± 73.1	251.4 ± 59.3	0.233	0.793	0.081
Peak Torque KF_{ECC}, N.m · kg_{BM}	3.2 ± 1.0	3.9 ± 1.2	4.1 ± 0.8	4.077	0.021	0.323
Peak Torque KF_{ECC}, N.m · $kg_{BM}^{-0.57}$	20.6 ± 6.5	23.4 ± 6.5	24.3 ± 4.8	1.903	0.157	0.227
Peak Torque KF_{CC}, N.m	103.9 ± 23.5	105.2 ± 19.9	99.6 ± 22.1	0.549	0.580	0.124
Peak Torque KF_{CC}, N.m · kg_{BM}	1.4 ± 0.2	1.7 ± 0.3	1.6 ± 0.3	3.640	0.031	0.307
Peak Torque KF_{CC}, N.m · $kg_{BM}^{-0.478}$	13.3 ± 2.5	14.6 ± 2.4	13.9 ± 2.8	1.252	0.292	0.186
Peak Torque KE_{ECC}, N.m	154.2 ± 39.4	152.8 ± 35.9	151.7 ± 32.0	0.024	0.976	0.026
Peak Torque KE_{ECC}, N.m · kg_{BM}	2.1 ± 0.5	2.5 ± 0.6	2.5 ± 0.5	2.717	0.073	0.268
Peak Torque KE_{ECC}, N.m · $kg_{BM}^{-0.386}$	29.4 ± 6.7	31.0 ± 6.5	31.0 ± 6.0	0.366	0.695	0.102

Additionally, significant difference was also noted for the concentric mode of knee flexion expressed in N·m·kg. Again, goalkeepers (1.4 ± 0.2) obtained poorer results compared to defenders (1.7 ± 0.3) and attackers (1.6 ± 0.3). The Bonferroni post hoc comparison noted that differences were only significant between goal keepers and defenders (mean difference = 0.29; *p* = 0.027).

DISCUSSION

This study examined the association of somatic and anthropometric characteristics with performance in field and laboratory tests. Hand grip strength, 2 Kg ball throw and all laboratory tests, were log transformed to remove potentially spurious effects associated with body size. In addition, variation by playing position was also considered. Results from the current study did not show differences between attackers and defenders, with regarding to log-transformed variables. Playing position was a significant source of variation, with goalkeepers, on average, being the less fit players compared to their outfield peers. The contrasting trends by position may reflect, in part, age- and maturity-associated variation, and perhaps demands of specific positions as the level of competition increases.

Roller hockey players tend to initiate formal practice around 5 years of age, which is consistent with the current trend on field hockey players (Elferink-Gemser, Visscher, Lemmink, & Mulder, 2004). On the other hand, soccer and players tend to engage formal practice later on, around 9 years of age (Figueiredo, Goncalves, Coelho, et al., 2009). This is probably due, to the fact that roller hockey players are exposed to sport specialization at earlier stages.

Skeletal and chronological ages (SA, CA, respectively) of this sample overlap considerably, where SA is, on average, in advance of CA. This is also apparent in adolescent soccer players (Figueiredo, Goncalves, Coelho, et al., 2009) and also in sports like baseball, American football, ice hockey, basketball and swimming (Coelho e Silva et al., 2010; Malina, 2011). Nevertheless, similarly to a sample of Under-14 soccer Portuguese soccer players, there was no variation in somatic maturation, SA and CA of roller hockey players, associated to playing position.

Players in this study presented mean statures between the 25th and 50th centiles and mean body masses between the 50th and 75th using US age specific percentiles (Kuczmarski et al., 2002) The elevated mass-for-stature probably reflected the advanced biological age of the players and perhaps the influence of systematic training on development of FFM (Malina et al., 2004) a greater FFM is likely indicative of greater muscle mass and likely greater strength, which has an influence on short-term field tests (Huijgen, Elferink-Gemser, Post, & Visscher, 2010; Negrete & Brophy, 2000). The trend for carrying more weight-for-height at late adolescence was also noted by the literature of soccer players in Europe and the Americas (Coelho e Silva et al., 2010; Huijgen et al., 2010; Malina et al., 2000). Mean relative fat (by densitometry, total body water) of elite young adult soccer players in four studies ranged from 6.2% to 9.7% (Malina, 2007). Roller hockey goalkeepers showed to be heavier and fatter than outfield players (mean difference of 11 Kg and 6 Kg, respectively. This trend was also visible in professional players, of the English premier league (Sutton, Scott, Wallace, & Reilly, 2009), and late adolescents and young adult Spanish players (17.31 ± 2.64 years) (Gil, Gil, Ruiz, Irazusta, & Irazusta, 2007), but not in senior male handball players (Srhoj, Marinovic, & Rogulj, 2002).

A recent longitudinal study (Roescher, Elferink-Gemser, Huijgen, & Visscher, 2010), investigated the development of the intermittent endurance capacity in a sample of 130 talented Dutch soccer players aged 14–18 years who became professional and nonprofessional in adulthood. Even though the interactions with growth and maturation were not considered, players who reached the professional league showed a differential development pattern compared to their counterparts, and similarly to our results, reported a direct relationship between intermittent endurance capacity and time spent in soccer activities (training plus independent practice). It is known that with growth and training, players can improve their performance by increasing aerobic output during a particular movement (Elferink-Gemser et al., 2006b). Young adults typically show a 15%–20% increase in maximal O2 uptake with training, although there may be a large intra individual variation due to genetic factors (Bouchard, 1992). Despite the arguments and research suggesting that prepubescent children are not capable of improving their endurance performance with training (Welsman et al., 1997), there is much evidence to suggest otherwise (Rowland & Boyajian, 1995).

Longitudinal data on boys from the Leuven Longitudinal Twin Study suggested a simultaneous regulation of the timing of maximum growth in body dimensions and aerobic fitness during adolescence (Geithner et al., 2004). The results from the Training of Young Athletes (TOYA) study indicated that the maximal O_2 consumption, adjusted for age and body dimensions, increased with a pubertal status in male athletes (Baxter-Jones, Goldstein, & Helms, 1993). In general, the available data indicate that age-related increases in the maximal O_2 consumption are mostly mediated by changes in size dimensions, as the hematological components of oxygen delivery and the oxidative mechanisms of the exercise muscle are related to body dimensions and muscle mass (Armstrong & Welsman, 1994; Eisenmann, Pivarnik, & Malina, 2001). However, the individuality of timing and the tempo of maturation and year-to-year changes in body weight and the maximal O_2 consumption may be masked by maturity effects (Malina et al., 2004)..

Absolute values for peak VO_2 (Table 3), were higher than those previously reported for similar age range in the general population (Beunen et al., 2002; Geithner et al., 2004a, 2004b) However, the peak VO_2 values were comparable to male athletes of similar age in several team sports but lower than athletes in endurance-based individual sports like triathlon, long-distance running, cross country skiing, swimming (Bunc, 2004). Although roller hockey is not an endurance sport per se, it has been suggested that high values of cardiopulmonary functions may be important for players to maintain a high level of activity during the entire game (Kingman and Dyson, 1997) and for effective recovery from high-intensity, short burst movements (Bonafonte, .Pérez, & Marrero, 1994)

Several sport-specific protocols have been proposed for the evaluation of maximal-intensity performance, particularly protocols dealing with repeated-sprint ability assessments in team sports, such as soccer (Impellizzeri et al., 2008; Spencer, Fitzsimons, Dawson, Bishop, & Goodman, 2006; Wragg, Maxwell, & Doust, 2000). However, to author's knowledge, there are no specific protocols in skates to assess the level of functional fitness of roller hockey players. Similarly, there is a lack of valid, reliable and standardized methods of assessing maximal short-term power outputs in children and adolescents (Van Praagh & Dore, 2002). The WAnT has been used extensively and in a variety of settings with pediatric populations spanning childhood through adolescence (Bar-Or, 1987). Meanwhile, the specificity of the WAnT for athletes in non-cycling sports has not been yet established (Carvalho, Silva, et al., 2011). Adolescent roller hockey players in the present study generated values of P-

WAnT and M-WAnT (Table 3) higher for peak and mean power comparable with male non-athletes of corresponding ages (Almuzaini, 2007). On the other hand, hockey players had lower short term power output compared to athletes of the same age and young adults in several other team sports (Apostolidis, Nassis, Bolatoglou, & Geladas, 2004; Carvalho, Silva, et al., 2011).

The results seem to suggest, therefore, that factors like training may interact in the expression of short-term power outputs in young athletes. The metabolic profile of WAnT is highly anaerobic (Beneke, Pollmann, Bleif, Leithauser, & Hutler, 2002; Micklewright, Alkhatib, & Beneke, 2006). It has been demonstrated that energy is supplied mostly by glycolysis (~ 50%) and phosphorylcreatine (PCr) breakdown (~ 30%) with a minor aerobic component (~ 20%) (Beneke et al., 2002). However, neither the availability of anaerobic energy nor the rate of anaerobic energy release seems to limit performance during the WAnT, indicating that the rate of ATP utilization may be the performance-limiting factor during the 30-s all-out cycling performance (Calbet, De Paz, Garatachea, Cabeza de Vaca, & Chavarren, 2003). Short-term maximum intensity performance, absolute and relative to body mass, is lower in children than adolescents and adults. It has been suggested that limitations of glycolysis, PCr breakdown and oxidative re-phosphorylisation confine short-term maximum performances throughout pubertal development (Beneke, Hutler, & Leithauser, 2007). These interpretations may be masked by the limitations, using ratio standards (e.g., Watts · kg^{-1} body mass), to remove potentially spurious effects associated with body size (Tanner, 1949a). Body mass has been the most used size variable when modeling power outputs, but it has been argued that other dimensions can serve as alternatives when using allometric scaling to compare individuals (Nevill & Bate, 2005). In the present study, the absolute WAnT peak output was affected by variation in playing position, with goalkeepers performing better than their outfield peers. As expected, these differences disappeared after considering the allometric scaled WAnT peak output (Watts · $kg_{BM}^{-0.952}$).

Maximal isokinetic strength was comparable to young male athletes in basketball (Gerodimos et al., 2003) and soccer (Forbes et al., 2009). Given the observed correlation between body mass and isokinetic maximal moments of force in the knee joint, proportional, multiplicative allometric modeling was used to partition size differences. Isokinetic strength outputs are also often expressed as a ratio standard to adjust for variation in body size (Gerodimos et al., 2003). However, spurious correlations, potential misinterpretation of the data, and inaccurate conclusions are limitations of the ratio method (Nevill, Ramsbottom & Wikkiams, 1992a; Tanner, 1949a), especially when applied with children and adolescents. Samples of young athletes not only include inter-individual variability in body size and composition, but also contrasting training backgrounds, level of performances, and biological maturation. Results of allometric modeling indicated size exponents in relation to maximal isokinetic moments of force ranging from 0.386 to 5.98 (Table 7) for body mass. The exponents are below the theoretically predicted value of 1.0 based on theory of geometric similarity (Jaric, 2002; Jaric, Mirkov, & Markovic, 2005) and are within the limits of in the 95% confidence interval. This is consistent with reported body size exponents for isokinetic maximal moments of force in other samples of young athletes (Weir, Housh, Johnson, Housh, & Ebersole, 1999).

Carvalho et al., (2011), by incorporating the maturity indicator term in the proportional multiplicative allometric modeling, it´s seen that the size exponents for body mass were reduced. These results suggest that the influence of biological maturation in isokinetic maximal torque in both knee extensors and flexors muscles may be mainly though maturity associated variation in body mass. This is consistent with the general assumption that somatic growth is the major influence on strength during childhood and adolescence, especially the changes in the quantity of muscle (Jones & Round, 2000). The main influence on muscle development during puberty is mediated by the actions of growth hormones, somatomedins, insulin, thyroid hormones and by the large increase in testosterone (Round et al., 1999). Also, changes in lever ratios in the skeleton due to longitudinal growth of segments influence the expression of force (Armstrong & McManus, 2011). Thus, the results in the study are consistent with the argument that maximal force can be generated by skeletal muscle is primarily a function muscle size (Armstrong & McManus, 2011), particularly during sexual maturation.

The impact of variation by playing position, in French amateur senior soccer players, was also considered for isokinetic evaluations (Tourny-Chollet, Leroy, Léger,

& Beuret-Blanquart, 2000). Isokinetic peak torque was accessed on a concentric mode at different velocities (60º/s, 120º/s and 240º/s). Statistically differences, favoring attackers, were only seen at 60º/s, for hamstrings and quadriceps, and at 120º/s, for hamstrings. With regard to the present sample differences in the relative peak torque ($Nm \cdot Kg^{-1}$), were noted, on the concentric mode for Knee extension and flexion at 60º/s, favoring defenders and attackers when compared to goalkeepers. These results could be attributed to the constant skating activities of outfield players, like rolling, pushing, sprinting, slide and stopping (Kingman & R. Dyson, 1997).

CONCLUSIONS

In summary, this study showed that young roller hockey players differed by position in physique and functional fitness. Anthropometric, lower limb explosive strength, short-term field and laboratory tests and aerobic endurance characteristics, corresponded to the most prominent differences between players of different positions. Defenders and attackers tended to be similar to each other and more fit than goalkeepers. Goalkeepers were heavier (with more FM) and presented better scores than outfield players in the WAnT peak outputs. It is possible that variation in body size and maturation interacts with sport orientation at younger ages of sport participation and that maturity-associated variation of functional performances may be due to variation in body size. All laboratory tests had a positive correlation with body mass and need appropriate normalization. All allometric coefficients observed in the sample of adolescent hockey players appeared to be specific to the sport which selects and retains athletes who tend to carry elevated mass-for-stature, compared to the general population. After scaling for body mass, functional fitness did not differ among goalkeepers, defenders and attackers. Future research, should consider more sport-specific tests to assist coaches in profiling athletes by playing position and evaluation adaptations to training.

REFERENCES

Aagaard, P., Simonsen, E. B., Magnusson, S. P., Larsson, B., & Dyhre-Poulsen, P. (1998). A new concept for isokinetic hamstring: quadriceps muscle strength ratio.. *The American journal of sports medicine, 26*(2), 231-237.

Abdelkrim, N. N., Chaouachi, A., Charmari, k., Chttara, M., & Castagna, C. (2010). Positionalrole andcompetitive-level differences in elite-levelmen's basketballplayers. *Journal of Strength and Conditioning Research, 24*(5), 1346-1355.

Acheson, R. M. (1966). Maturation of the skeleton. In F. Falkner (Ed.), *Human development* (pp. 465-502). Philadelphia: Sauders.

Almuzaini, K. S. (2007). Muscle function in Saudi children and adolescents: relationship to anthropometric characteristics during growth. *Pediatric Exercise Science, 19*(3), 319-333.

Apostolidis, N., Nassis, G. P., Bolatoglou, T., & Geladas, N. D. (2004). Physiological and technical characteristics of elite young basketball players. *The Journal of Sports Medicine and Physical Fitness, 44*(2), 157-163.

Ares, P. (2005). *Hockey sobre patines: Estudio de las demandas fisiologicas en competición, análisis del perfil fisiológico funcional, desarrollo y validación de un modelo de valoración funcional específica orientado al jugador de campo.* (Doctoral Thesis), University of Oviedo, Oviedo.

Armstrong, N., & McManus, A. M. (2011). Physiology of ELite Young Male Athletes. In N. Armstrong & A. M. McManus (Eds.), *The Elite Young Athlete* (Vol. 56, pp. 1-22). Basel: Karger.

Armstrong, N., & Welsman, J. R. (1994). Assessment and interpretation of aerobic fitness in children and adolescents. *Exercise and sport sciences reviews, 22*, 435-476.

Armstrong, N., & Welsman, J. R. (2001). Peak oxygen uptake in relation to growth and maturation in 11- to 17-year-old humans. *European Journal of Applied Physiology, 85*(6), 546-551.

Baltzopoulos, V., Williams, J. G., & Brodie, D. A. (1991). Sources of Error in lsokinetic Dynamometry: Effects of Visual Feedback on Maximum Torque Measurements. *Journal of Orthopaedic & Sports Physical Therapy*(13), 138-142.

Bar-Or, O. (1987). The Wingate anaerobic test. An update on methodology, reliability and validity. *Sports Medicine, 4*(6), 381-394.

Baxter-Jones, A., Goldstein, H., & Helms, P. (1993). The development of aerobic power in young athletes.. *Journal of applied physiology, 75*(3), 1160-1167.

Bayer, L. M., & Bayle, N. (1959). Growth Diagnosis: Selected Methods for Interpreting and Predicting Development from One Year to Maturity (pp. 45-58). Chicago: University of Chicago Press.

Ben Abdelkrim, N., El Fazaa, S., & El Ati, J. (2007). Time-motion analysis and physiological data of elite under-19-year-old basketball players during competition. *British Journal of Sports Medicine, 41*(2), 69-75; discussion 75.

Beneke, R., Hutler, M., & Leithauser, R. M. (2007). Anaerobic performance and metabolism in boys and male adolescents. *European Journal of Applied Physiology, 101*(6), 671-677.

Beneke, R., Pollmann, C., Bleif, I., Leithauser, R. M., & Hutler, M. (2002). How anaerobic is the Wingate Anaerobic Test for humans? *European Journal of Applied Physiology, 87*(4-5), 388-392.

Beunen, Malina, R. M., Renson, R., Simons, J., Ostyn, M., & Lefevre, J. (1992). Physical activity and growth, maturation and performance: a longitudinal study.. *Medicine and Science in Sports and Exercise, 24*(5), 576-585.

Beunen, G., Baxter-Jones, A. D., Mirwald, R. L., Thomis, M., Lefevre, J., Malina, R. M., & Bailey, D. A. (2002). Intraindividual allometric development of aerobic power in 8- to 16-year-old boys. *Medicine and Science in Sports and Exercise, 34*(3), 503-510.

Beunen, G., & Malina, R. M. (1988). Growth and physical performance relative to the timing of the adolescent spurt. *Exercise and Sport Science Reviews, 16*, 503-540.

Bonafonte, L. F., Pérez, J. R., & Marrero, R. M. (1994). Physiological characteristics of roller-hockey: Study in the sports field. *Archivos de Medicina del Deporte, 11*(44), 345-350.

Bosco, C. (1994). *La valoration de la fuerza com el test de Bosco* (J. Riu, Trans.). Barcelona: Editorial Paidotribo.

Bouchard, C. (1992). *Annales de medecine interne, 143*(7), 463-471.

Bunc, V. (2004). Physiological and functional characteristics of adolescent athletes in several sports: implications for talent identification. In M. J. Coelho e Silva & R. M. Malina (Eds.), *Children and youth in organized sports* (pp. 247-257). Coimbra Coimbra University Press.

Burr, J. F., Jamnik, R. K., Baker, J., Macpherson, A., Gledhill, N., & McGuire, E. J. (2008). Relationship of physical fitness test results and hockey playing potential in elite-level ice hockey players. *Journal of strength and conditioning research / National Strength & Conditioning Association, 22*(5), 1535-1543.

Calbet, J. A., De Paz, J. A., Garatachea, N., Cabeza de Vaca, S., & Chavarren, J. (2003). Anaerobic energy provision does not limit Wingate exercise performance in endurance-trained cyclists. TrialRandomized Controlled Trial. *Journal of Applied Physiology, 94*(2), 668-676.

Carvalho, H. M., Coelho, E. S. M., Valente-Dos-Santos, J., Goncalves, R. S., Philippaerts, R., & Malina, R. (2011). Scaling lower-limb isokinetic strength for biological maturation and body size in adolescent basketball players. *European Journal of Applied Physiology*.

Carvalho, H. M., Coelho, E. S. M., Valente-Dos-Santos, J., Goncalves, R. S., Philippaerts, R., & Malina, R. (2012). Scaling lower-limb isokinetic strength for biological maturation and body size in adolescent basketball players. *European Journal of Applied Physiology, 112*(8), 2881-2889.

Carvalho, H. M., Coelho, E. S. M. J., Ronque, E. R., Goncalves, R. S., Philippaerts, R. M., & Malina, R. M. (2011). Assessment of reliability in isokinetic testing among adolescent basketball players. *Medicina, 47*(8), 446-452.

Carvalho, H. M., Silva, M. J., Figueiredo, A. J., Goncalves, C. E., Philippaerts, R. M., Castagna, C., & Malina, R. M. (2010). Predictors of maximal short-term power outputs in basketball players 14-16 years. *European Journal of Applied Physiology*.

Carvalho, H. M., Silva, M. J., Figueiredo, A. J., Goncalves, C. E., Philippaerts, R. M., Castagna, C., & Malina, R. M. (2011). Predictors of maximal short-term power outputs in basketball players 14-16 years. *Eur J Appl Physiol, 111*(5), 789-796

Coelho-e-Silva, M. J., Figueiredo, A. J., Carvalho, H. M., & Malina, R. M. (2008). Functional capacities and sport-specific skills of 14- to 15-year-old male basketball players: Size and maturity effects *European Journal of Sport Science 8*(5), 277-285.

Coelho e Silva, M. J., Figueiredo, A. J., Simoes, F., Seabra, A., Natal, A., Vaeyens, R., .Malina, R. M. (2010). Discrimination of u-14 soccer players by level and position. *International Journal of Sports Medicnine, 31*(11), 790-796.

Coelho E Silva MJ, M. C. H., Goncalves CE, et al. (2010). Growth, maturation, functional capacities and sport-specific skills in 12–13-year old-basketball players. *J Sports Med Phys Fitness, 50*, 883-891.

Cox, M. H., Miles, D. S., Verde, T. J., & Rhodes, E. C. (1995). Applied physiology of ice hockey. *Sports medicine, 19*(3), 184-201.

Drinkwater, E. J., Pyne, D. B., & McKenna, M. J. (2008). Design and interpretation of anthropometric and fitness testing of basketball players. *Sports medicine, 38*(7), 565-578.

Eisenmann, J. C., Pivarnik, J. M., & Malina, R. M. (2001). Scaling peak VO2 to body mass in young male and female distance runners. *Journal of Applied Physiology, 90*(6), 2172-2180.

Elferink-Gemser, M. T., Visscher, C., Lemmink, K. A., & Mulder, T. W. (2004). Relation between multidimensional performance characteristics and level of performance in talented youth field hockey players. *Journal of Sports Sciences, 22*(11-12), 1053-1063.

Elferink-Gemser, M. T., Visscher, C., Richart, H., & Lemmink, K. A. (2004). Development of the Tactical Skills Inventory for Sports. *Perceptual and Motor Skills, 99*(3 Pt 1), 883-895.

Elferink-Gemser, M. T., Visscher, C., van Duijn, M. A., & Lemmink, K. A. (2006a). Development of the interval endurance capacity in elite and sub-elite youth field hockey players. *British Journal of Sports and Medice, 40*(4), 340-345.

Elferink-Gemser, M. T., Visscher, C., van Duijn, M. A., & Lemmink, K. A. (2006b). Development of the interval endurance capacity in elite and sub-elite youth field hockey players. *British Journal of Sports Medicine, 40*(4), 340-345.

EUROFIT. (1988). *Handbook for the European Test of Physical Fitness*. Rome: Council of European Committee for Development in Sports.

Figueiredo, A. J., Goncalves, C. E., Coelho-e-Silva, M. J., & Malina, R. M. (2009). Youth soccer players, 11-14 years: maturity, size, function, skill and goal orientation. *Annals of Human Biology, 36*(1), 60-73.

Figueiredo, A. J., Goncalves, C. E., Coelho, E. S. M. J., & Malina, R. M. (2009). Characteristics of youth soccer players who drop out, persist or move up. *Journal of Sports Sciences, 27*(9), 883-891.

Forbes, H., Bullers, A., Lovell, A., McNaughton, L., Polman, R., & Siegler, J. (2009). Relative torque profiles of elite male youth football-ers: effects of age and pubertal development. *International Journal of Sports Medicine*(30), 592-597.

Geithner, C. A., Thomis, M. A., Vanden Eynde, B., Maes, H. H., Loos, R. J., Peeters, M., Beunen, G. P. (2004). Growth in peak aerobic power during adolescence. *Medicine & Science in Sports Exercise, 36*(9), 1616-1624.

Gerodimos, V., Mandou, V., Zafeiridis, A., Ioakimidis, P., Stavropoulos, N., & Kellis, S. (2003). Isokinetic peak torque and hamstring/quadriceps ratios in young basketball players. Effects of age, velocity, and contraction mode. *Journal of Sports Medicine and Physical Fitness, 43*(4), 444-452.

Gil, S. M., Gil, J., Ruiz, F., Irazusta, A., & Irazusta, J. (2007). Physiological and anthropometric characteristics of young soccer players according to their playing position: relevance for the selection process. *Journal of Strength Conditioning and Research, 21*(2), 438-445.

Greulich, W. W., & Pyle, S. I. (1959). *Radiographic Atlas of Skeletal Development of the Hand and Wrist* (2nd ed.). Stanford, CA: Stanford University Press.

Holloszy, J. O., Rennie, M. J., Hickson, R. C., Conlee, R. K., & Hagberg, J. M. (1977). Physiological consequences of the biochemical adaptations to endurance exercise. *Annals of the New York Academy of Sciences, 301*, 440-450.

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise, 41*(1), 3-13.

Housh, T. J., Stout, J. R., Weir, J. P., Weir, L. L., Housh, D. J., Johnson, G. O., & Evans, S. A. (1995). Relationships of age and muscle mass to peak torque in high school wrestlers. *Research Quarterly for Exercise & Sport, 66*(3), 256-261.

Huijgen, B. C., Elferink-Gemser, M. T., Post, W., & Visscher, C. (2010). Development of dribbling in talented youth soccer players aged 12-19 years: a longitudinal study. *Journal of Sports Sciences, 28*(7), 689-698.

IDP. (2011). *Estatística do associativismo desportivo*. Lisbon: Instituto do Desporto de Portugal.

Impellizzeri, F. M., Rampinini, E., Castagna, C., Bishop, D., Ferrari Bravo, D., Tibaudi, A., & Wisloff, U. (2008). Validity of a repeated-sprint test for football. *International Journal of Sports Medicine, 29*(11), 899-905.

Inbar, O., Bar-Or, O., & Skinner, J. S. (1996). *The Wingate anaerobic test*. Champaign, IL Human Kinetics.

Jaric, S. (2002). Muscle strength testing: use of normalisation for body size. *Sports Medicine, 32*(10), 615-631.

Jaric, S., Mirkov, D., & Markovic, G. (2005). Normalizing physicalperformance tests for body size: a proposal for standardization. *Journal of Strength Conditioning & Research,19*(2), 467-474.

Jones, D. A., & Round, J. M. (2000). *Strenght muscle in growth*. Oxford: Oxford University Press.

Khamis, H. J., & Roche, A. F. (1994). Predicting adult stature without using skeletal age: the Khamis-Roche method. *Pediatrics, 94*(4 Pt 1), 504-507.

Kingman, J. C., & Dyson, R. (1997). Analysis of roller hockey match play. *J Hum Mov Stud, 32*, 235-251.

Kingman, J. C., & Dyson, R. (1997). Player position, match half and score effects on the time and motion characteristics of roller hockey match play. *J Hum Mov Stud, 33*, 15-29.

Kuczmarski, R. J., Ogden, C. L., Grummer-. Strawn, L. M., Flegal, K. M., Mei, Z., Wei, R., Johnson, C. L. (2002). 2000 CDC Growth Charts for the United States: Methods and Development (D. o. H. a. H. Services, Trans.) *Vital and Health Statistics* (Vol. 11). Washington, DC.

Lawrence, S., & Polglaze, T. (2000). Protocols for the physiological assessment of male and female field hockey players. In C. J. Gore (Ed.), *Physiological Tests for Elite Athletes. Australian Sports Commision*. Champaign, IL: Human Kinetics.

Leatt, P., Shephard, R. J., & Plyley, M. J. (1987). Specific muscular development in under-18 soccer players. *J Sports Sci, 5*(2), 165-175.

Leger, L. A., Mercier, D., Gadoury, C., & Lambert, J. (1988). The multistage 20 metre shuttle run test for aerobic fitness. *J Sports Sci, 6*(2), 93-101.

Lemmink, K. A., Elferink-Gemser, M. T., & Visscher, C. (2004). Evaluation of the reliability of two field hockey specific sprint and dribble tests in young field hockey players. *British Journal of Sports Medicine, 38*(2), 138-142.

Lemmink, K. A., Verheijen, R., & Visscher, C. (2004). The discriminative power of the Interval Shuttle Run Test and the Maximal Multistage Shuttle Run Test for playing level of soccer. *The Journal of Sports Medicine and Physical Fitness, 44*(3), 233-239.

Leone, M., Leger, L. A., Lariviere, G., & Comtois, A. S. (2007). An on-ice aerobic maximal multistage shuttle skate test for elite adolescent hockey players. *International Journal of Sports Medicine, 28*(10), 823-828.

Lohman, T. G., Roche, A. F., & Martorell, R. (1988). *Anthropometric standardization reference manual*. Champaign, IL: Human Kinetics.

Malina, R., Bouchard, C., & Bar-Or, O. (2004). *Growth, maturation, and physical activity* (2nd ed.). Champaign, IL: Human Kinetics.

Malina, R. M. (2007). Body composition in athletes: assessment and estimated fatness. *Clin Sports Med, 26*(1), 37-68.

Malina, R. M. (2011). Skeletal age and age verification in youth sport. *Sports medicine, 41*(11), 925-947.

Malina, R. M., Bouchard, C., & Bar-Or, O. (2004). *Growth, maturation, and physical activity* (2nd ed.). Champaign, IL: Human Kinetics.

Malina, R. M., Chamorro, M., Serratosa, L., & Morate, F. (2007). TW3 and Fels skeletal ages in elite youth soccer players. *Annals of Human Biology, 34*(2), 265-272.

Malina, R. M., Claessens, A. L., Van Aken, K., Thomis, M., Lefevre, J., Philippaerts, R., & Beunen, G. P. (2006). Maturity offset in gymnasts: application of a prediction equation. *Medicine & Science in Sports & Exercise 38*(7), 1342-1347.

Malina, R. M., Cumming, S. P., Kontos, A. P., Eisenmann, J. C., Ribeiro, B., & Aroso, J. (2005). Maturity-associated variation in sport-specific skills of youth soccer players aged 13-15 years. *Journal of Sports Sciences, 23*(5), 515-522.

Malina, R. M., Eisenmann, J. C., Cumming, S. P., Ribeiro, B., & Aroso, J. (2004). Maturity-associated variation in the growth and functional capacities of youth football (soccer) players 13-15 years. *European Journal of Applied Physiology, 91*(5-6), 555-562.

Malina, R. M., Pena Reyes, M. E., Eisenmann, J. C., Horta, L., Rodrigues, J., & Miller, R. (2000). Height, mass and skeletal maturity of elite Portuguese soccer players aged 11-16 years. *Journal of Sports Sciences, 18*(9), 685-693.

Malina, R. M., Pena Reyes, M. E., Figueiredo, A. J., Coelho, E. S. M. J., Horta, L., Miller, R.,. Morate, F. (2010). Skeletal age in youth soccer players: implication for age verification. *Clinical Journal of Sport Medicine, 20*(6), 469-474.

Mendo, A. H., & Argilaga, M. T. (2002). Behavioral structure in sociomotor sports: Roller-hockey. *Quality & Quantity, 36*, 347–378.

Micklewright, D., Alkhatib, A., & Beneke, R. (2006). Mechanically versus electro-magnetically braked cycle ergometer: performance and energy cost of the Wingate Anaerobic Test]. *European Journal of Appl Physiol, 96*(6), 748-751.

Mirwald, R. L., Baxter-Jones, A. D., Bailey, D. A., & Beunen, G. P. (2002). An assessment of maturity from anthropometric measurements. *Medicine & Science in Sports & Exercise, 34*(4), 689-694.

Mohamed, H., Vaeyens, R., Matthys, S., Multael, M., Lefevre, J., Lenoir, M., & Philppaerts, R. (2009). Anthropometric and performance measures for the development of a talent detection and identification model in youth handball. *Journal of Sports Sciences, 27*(3), 257-266.

Mohr, M., Krustrup, P., & Bangsbo, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. *Journal of Sports Scices, 21*(7), 519-528.

Mueller, W. H., & Martorell, R. (1988). Reliability and accuracy of measurement. In T. G. Lohman, A. F. Roche & R. Martorell (Eds.), *Anthropometric standardization reference manual* (pp. 83-86). Champaign, IL: Human Kinetics.

Negrete, R., & Brophy, J. (2000). The relationship between isokinetic open and closed chain lower extremity strength and functional performance. *Journal of Sport Rehabilitation, 9*, 46-61.

Nevill, A., & Holder, R. (1994). Modelling maximum oxygen uptake: A case study in non-linear regression model formulation and comparison. *Journal of The Royal Statistical Society, 43*(4), 653-666.

Nevill, A. M., & Bate, S. (2005). Allometric cascade model and metabolic rate. *Respiratory physiology & neurobiology, 146*(1), 1-2; author reply 3-4.

Nevill, A. M., Cooke, C. B., Holder, R. L., Ramsbottom, R., & Williams, C. (1992). Modelling bivariate relationships when repeated measurements are recorded on more than one subject. *European Journal of Applied Physiology and Occupational Physiology, 64*(5), 419-425.

Nevill, A. M., Ramsbottom, R., & Williams, C. (1992a). Scaling physiological measurements for individuals of different body size. *European Journal of Applied Physiology and Occupational Physiology, 65*(2), 110-117.

Nevill, A. M., Ramsbottom, R., & Williams, C. (1992b). Scaling physiological measurements for individuals of different body size. *European Journal of Applied Physiology and Occupational Physiology 65*(2), 110-117.

O'Brien, T. D., Reeves, N. D., Baltzopoulos, V., Jones, D. A., & Maganaris, C. N. (2009). Strong relationships exist between muscle volume, joint power and whole-body external mechanical power in adults and children. *Experimental Physiology 94*(6), 731-738.

Philippaerts, R. M., Vaeyens, R., Janssens, M., Van Renterghem, B., Matthys, D., Craen, R., Malina, R. M. (2006). The relationship between peak height velocity and physical performance in youth soccer players. *Journal of Sports Sciences, 24*(3), 221-230.

Reilly, T. G., L. (2005). *Bilateral isokinetic knee strength pro-files in trained junior soccer players and untrained individuals*. Paper presented at the Science and Football: The Proceedings of the 5th World Congress on Sports Science and Football.

Roche, A., Tyleshevski, F., & Rogers, E. (1983). Non-invasive measurement of physical maturity in children. *Research Quarterly for Exercise & Sport, 54*, 364-371.

Roche, A. F., Chumlea, C. W., & Thissen, D. (1988). *Assessing the Skeletal Maturity of the Hand-Wrist: Fels Method*. Springfield, IL: CC Thomas.

Roescher, C. R., Elferink-Gemser, M. T., Huijgen, B. C., & Visscher, C. (2010). Soccer endurance development in professionals. *Int J Sports Medicine, 31*(3), 174-179.

Rosnow, R. L., & Rosenthal, R. (1996). Computing contrasts, effect sizes, and counternulls on other people’s published data: General procedures for research consumers. *Psychological Methods, 1*, 331-340.

Round, J., Jones, D., Honour, J., & Nevill, A. (1999). Hormonal factors in the development of differences in strength between boys and girls during adolescence: a longitudinal study. *Annals of Human Biology* (26), 49-62.

Rowland, T. W., & Boyajian, A. (1995). Aerobic response to endurance exercise training in children. *Pediatrics, 96*(4 Pt 1), 654-658.

Sale, D. G. (1991). Scaling: why is animal size so important? In W. H. JD, Green HJ (Ed.), *Physiological testing of the high performance athlete* (pp. 21–75): Human Kinetics, Champaign.

Sherar, L. B., Baxter-Jones, A. D., Faulkner, R. A., & Russell, K. W. (2007). Do physical maturity and birth date predict talent in male youth ice hockey players? *Journal of Sports Sciences, 25*(8), 879-886.

Slaughter, M. H., Lohman, T. G., Boileau, R. A., Horswill, C. A., Stillman, R. J., Van Loan, M. D., & Bemben, D. A. (1988). Skinfold equations for estimation of body fatness in children and youth. *Human Biology, 60*(5), 709-723.

Sobral, F. (1992). *Facdex : desenvolvimento somato-motor e factores de excelência desportiva na população escolar portuguesa* Lisboa.

Spencer, M., Fitzsimons, M., Dawson, B., Bishop, D., & Goodman, C. (2006). Reliability of a repeated-sprint test for field-hockey. *Journal of science and Medicine in Sport, 9*(1-2), 181-184.

Srhoj, V., Marinovic, M., & Rogulj, N. (2002). Position specific morphological characteristics of top-level male handball players. *Collegium Antropologicum, 26*(1), 219-227.

Sutton, L., Scott, M., Wallace, J., & Reilly, T. (2009). Body composition of English Premier League soccer players: influence of playing position, international status, and ethnicity. *Journal of Sports Sciences, 27*(10), 1019-1026.

Tan, F. H. Y., Polglaze, T., Dawson, B., & Cox, G. (2009). Anthropometric and fitness characteristics of elite australian female waterpolo players. *Journal of Strength and Conditioning Research, 23*(5), 1530-1536.

Tanner, J. M. (1949a). Fallacy of per-weight and per-surface area standards, and their relation to spurious correlation. *Journal of applied physiology, 2*(1), 1-15.

Tanner, J. M. (1949b). The relation between serum cholesterol and body build in healthy young men. *The Journal of physiology, 109*(1-2), Proc, 13.

Tanner, J. M. (1962). *Growth at adolescence* (2nd ed.). Oxford: Blackwell.

Tanner, J. M., Healy, M. J. R., Goldstein, H., & Cameron, N. (2001). *Assessment of Skeletal Maturity and Prediction of Adult Height (TW3 Method)* (3rd ed.). London: Saunders.

Tourny-Chollet, C., Leroy, D., Léger, H., & Beuret-Blanquart, F. (2000). Isokinetic knee muscle strength of soccerplayers according to their position. *Isokinetic knee muscle strength of soccer players according to their position*(8), 187-193.

Valente-Dos-Santos, J., Coelho, E. S. M. J., Simoes, F., Figueiredo, A. J., Leite, N., Elferink-Gemser, M. T., Sherar, L. (2012). Modeling developmental changes in functional capacities and soccer-specific skills in male players aged 11-17 years. *Pediatric Exercise Science, 24*(4), 603-621.

Van Praagh, E. (1998). Measuring Maximal Short-Term Power Output During Growth. In E. Van Praagh (Ed.), *Pediatric Anaerobic Performance* (pp. 155-189). Champaing, IL: Human Kinetics.

Van Praagh, E., & Dore, E. (2002). Short-term muscle power during growth and maturation. *Sports Medicine, 32*(11), 701-728.

Weir, J. P., Housh, T. J., Johnson, G. O., Housh, D. J., & Ebersole, K. T. (1999). Allometric scaling of isokinetic peak torque: the Nebraska Wrestling Study.

European Journal of Applied Physiology and Occupational Physiology, 80(3), 240-248.

Welsman, J. R., Armstrong, N., Kirby, B. J., Winsley, R. J., Parsons, G., & Sharpe, P. (1997). Exercise performance and magnetic resonance imaging-determined thigh muscle volume in children.. *European Journal of Applied Physiology and Occupational Physiology, 76*(1), 92-97.

Wragg, C. B., Maxwell, N. S., & Doust, J. H. (2000). Evaluation of the reliability and validity of a soccer-specific field test of repeated sprint ability. *European Journal of Applied Physiology, 83*(1), 77-83.