João Miguel Santos Bruno

SHORT-TERM POWER OUTPUT PROFILE IN YOUTH SOCCER PLAYERS

Master Dissertation in Sports Training for Children and Youth, presented to the Faculty of Sports Science and Physical Education of the University of Coimbra

December 2021

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COIMBRA

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Master's Dissertation in Sports Training for Children and Youth, presented to Faculty of Sports Science and Physical Education at the University of Coimbra to obtain a master's degree in training Sports for Children and Youth

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Coimbra, 2021

Bruno, J. (2021) Short-Term Power Output Profile in Youth Soccer Players. Master Dissertation to a obtain a master's degree in Sports Training for Children and Youth. University of Coimbra, Portugal.

ACKNOWLEDGMENTS

To all the people who accompanied me on this academic journey, my sincere thanks for their encouragement and guidance in various educational activities.

First of all, I would like to sincerely thank my advisor, Prof. Dr. Manuel João Coelho e Silva, for his continuous support. Over several months, he was concerned about my academic progress. The pressure he exerted in developing several details becomes central to my development, both as a person and a student.

Secondly, I would like to thank Prof. Dr. João Pedro Duarte for all his support over time and the tips he gave me to evolve as a student; his simplicity and ability to pay attention to his students is notorious.

I would also like to thank other teachers who made me evolve along this journey but unfortunately could not be my advisors. Thank you very much to Prof. Dr. Hugo Sarmento, Prof. Dr. Luis Rama, and MSc Diogo Martinho for all the learnings over time and patience in answering my questions as a student.

Last but not least, I want to thank all my family who over the years shared my concerning to the university. For all the help possible in difficult times, thank you very much on my part.

RESUMO

O objetivo deste estudo foi examinar protocolos maximais, tais como, o teste Wingate (WanT) associado à composição corporal e variáveis fisiológicas. Poderá também ocorrer uma inter-associação entre os processos de crescimento, a maturação biológica, o treino desportivo e fatores de performance em jovens futebolistas. A amostra foi composta por 89 jovens futebolistas, com idades compreendidas entre os 13.07 e os 14.97 anos, divididos em guarda-redes (n=8), defesas (n=33), médios (n=20) e avançados (n=28). As medidas antropométricas incluíram estatura, massa corporal e composição corporal obtida por pletismografia de deslocamento de ar. Adicionalmente, a performance foi obtida no teste WanT expressos em pico de potência por absoluto, por kg e por litros, e potência média por absoluto, por kg e por litros. Em termos de testes de performance, foram realizados o Squat jump e o Countermovement jump. Foi realizada uma correlação bivariada entre a idade cronológica, o indicador de timing da maturação biológica (% estatura matura predita) e um indicador de tempo (z-scores da % atingida da estatura matura predita). A idade cronológica relaciona-se com o pico de potência (r=0.558) e potência média (r=0.519). O indicador de timing (% estatura matura predita) apresenta maiores coeficientes com descritores de tamanho corporal, comparativamente ao indicador de tempo (z-scores da % atingida da estatura matura predita). Este indicador de timing está mais correlacionado com o pico de potência (r=0.677) e com a potência média (r=0.703) comparativamente ao indicador de tempo. Os jovens futebolistas acima da média, ou seja, avançados em termos de maturação somática eram mais altos, mais pesados e tinham maior volume da coxa massa isenta de gordura expressa em kg. Este grupo de jovens, acima da média em z-scores da % PMS obtiveram melhor score no protocolo WanT. Os guarda-redes demonstraram ter mais experiência de treino e pior pontuação de countermovement jump. Os defesas comparativamente aos médios, são mais altos, têm maior massa corporal e volume de coxa, contudo os médios têm melhores resultados referentes ao pico de potência e à potência média. O presente estudo sugeriu que as estratégias de bio-banding podem facilitar o desenvolvimento holístico do jovem futebolista, onde as idades perto do período de pico de velocidade de altura, ou seja, entre os 13 e os 15 anos são preponderantes para o desenvolvimento do treino das qualidades físicas, principalmente ao nível do desenvolvimento anaeróbio.

PALAVRAS-CHAVE: Jovem Atletas · *Futebol* · *Crescimento* · *Maturação Biológica* · *DEXA* · *Potência de curto-prazo* ·

ABSTRACT

This study aimed to examine maximal protocols, such as the Wingate test (WAnT) associated with body composition and physiological variables and performance variation in the Wingate test. There may also be an inter-association between growth processes, biological maturation, sports training, and performance factors in young soccer players. The sample consisted of 89 young soccer players, aged 13.07-14.97 years, divided into goalkeepers (n=8), defenders (n=33), midfielders (n=20) and forwards (n=28). Anthropometric measurements included height, body mass, and body composition obtained by air displacement plethysmography. Additionally, the performance was obtained in the Wingate test (WanT) expressed in peak power per absolute, per kg and liters, and average power per absolute, per kg and liters. In terms of performance tests, Squat jump and Countermovement jump were performed. A bivariate correlation was performed between chronological age, the timing indicator of biological maturation (% predicted mature height) and a tempo indicator (z-scores of the % predicted mature height achieved). Chronological age is related to peak power (r=0.558) and mean power (r=0.519). The timing indicator (% predicted mature height) has higher body size descriptors coefficients than the tempo indicator (z-scores of the % attained predicted mature height). This timing indicator is more correlated with peak power (r=0.677) and average power (r=0.703) compared to the tempo indicator. The young soccer players classified by above-mean, advanced in terms of somatic maturation, were taller, heavier, and had greater thigh volume and fat-free mass expressed in kg. This group of young people, above the mean in z-scores of % PMS obtained the best score in the WanT protocol. Goalkeepers demonstrated to have more training experience and worse countermovement jump scores. Compared to the midfielders, the defenders are taller and have greater body mass and thigh volume. However, the midfielders are better at referring to peak and average power. The present study suggested that bio-banding strategies can facilitate the holistic development of young soccer players, where ages close to the peak height velocity, i.e., between 13 and 15 years old, are predominant for the development of physical qualities training, mainly at the level of anaerobic development.

KEYWORDS: *Youth Athletes · Soccer · Growth · Biological Maturation · Dual-Energy X-Ray Absorptiometry · Short-term power ·*

LIST OF ABBREVIATIONS AND ACRONYMS

ADP	Air Displacement Plethysmography
AST	Cunningham and Faulkner treadmill anaerobic speed test
ATP/PC	Adenosine Triphosphate and Phosphocreatine
CM	Centimeters
CMJ	Countermovement jump
ES-r	Effect size
FAST	Field anaerobic shuttle test
FI	Fatigue index
Fopt	optimized applied force
GPS	Global positioning systems
HSR	High-speed running
Hz	Hertz
ISRT	Interval Shuttle Run Test
Km	Kilometers
L	Liters

Mmol/L	Millimoles per liter
MP	Mean power
PCr	Phosphocreatine
PHV	Peak Height Velocity
PMS	Predicted mature stature
PP	Peak power
Ppot	optimized peak power
RAST	Running-based anaerobic sprint test
RPM	Revolutions per minute
RSA	Repeated sprint ability
SJ	Squat jump
S*RPE	Session – rating perceived exertion
TMV	Thigh muscle volume
TO	Take-off
VHSR	Very high-speed running
Vopt	Optimized pedal velocity

WAnT	Wingate test

LIST OF TABLES

LIST OF FIGURES

INDEX

CHAPTER I - INTRODUCTION

In soccer academies, the process of identification or selection and subsequent development increase human and financial resources, which presupposes a high level of technical know-how (Sarmento et al., 2018; A. M. Williams et al., 2020). In addition, the issues of identification, selection, and development of athletes have raised methodological problems (Bergkamp et al., 2019; Johnston et al., 2018; A. M. Williams et al., 2020), and when it comes to soccer performance, it is always addressed in a multidimensional perspective, with physiological performance and biological maturation practices a great deal of attention on the part of practitioners and researchers, to optimize the training process for young athletes (Palucci Vieira et al., 2019; Salter et al., 2021; Chris Towlson et al., 2020).

Children's soccer is characterized by high-intensity moments of short duration, combined with periods of low intensity (Castagna et al., 2003; Dolci et al., 2020; Stølen et al., 2005). However, children are not mini-adults, and investigation should be directed towards this type of population (Palucci Vieira et al., 2019), where the performance of the match increases with age (Buchheit, Mendez-Villanueva, et al., 2010) and usually young soccer players perform about 5 to 8 km per soccer match, i.e., three to four km less than adults (Capranica et al., 2001; Carling et al., 2009; Castagna et al., 2010; Goto et al., 2015; Mohr et al., 2005; Rebelo et al., 2014; Reilly, Bangsbo, et al., 2000). As in senior soccer (P. S. Bradley et al., 2010; E Rampinini et al., 2007), the position also impacts the demands of the game (Aslan et al., 2012; Buchheit, Mendez-villanueva, et al., 2010; Buchheit, Mendez-Villanueva, et al., 2010; Strøyer et al., 2004), and hence, the central midfield covers greater distances compared to defenses and forwards (Castagna et al., 2010). The central defender performs shorter distances and performs activities with less intensity compared to full-backs/wing midfielders and forwards (Buchheit, Mendez-Villanueva, et al., 2010). Although there is some supporting evidence, there is some controversial research (Mendez-Villanueva et al., 2013) which suggests that when considering speed thresholds, young soccer players tend to perform more sprints (Buchheit, Mendez-villanueva, et al., 2010) and run the same total distance as adults (Harley et al., 2010). Some age-related differences are reported, such as running performance in both parts (Castagna et al., 2010), and young soccer players maintain high-intensity running in the second part better than adults (Castagna et al., 2003, 2010). Therefore, training processes must be appropriate for the age and biological maturation (Palucci Vieira et al., 2019). With recent literature reviews, it is possible to reduce gaps and thus provide professionals with the ability to make evidence-based decisions (Abarghoueinejad et al., 2021; Palucci Vieira et al., 2019; Chris Towlson et al., 2020).

Due to an enormous consideration of the physiological aspect, anaerobic power has been described as a discriminating factor between elite vs. sub-elite in youth soccer (Wing et al., 2020), with the Wingate test being the "gold standard" to assess this (Bar-Or, 1987; Vandewalle et al., 1987), and with the need for greater ecological validity, field tests have emerged as the RAST (Keir et al., 2013; Meckel et al., 2009) or Repeated Sprint Ability (RSA) (Bishop et al., 2011; Girard, Mendez-Villanueva, et al., 2011; Spencer et al., 2005; J. Taylor et al., 2015). Over the years, several criticisms have arisen related to this test, such as (I) the nature of the heating, and if the test is started stationary or continuous (II) obtaining the Power Peak and Average Mechanical Power in specific periods, because the Peak power of 1 second is significantly greater than 5 seconds, but when compared between 3 and 5 seconds, there are no statistically significant differences (III) inclusion of Inertia and internal resistance in the power calculation. According to (Chia et al., 1997) showed that the peak power and mean mechanical power in children aged nine years, adjusted to the inertia of the cycle ergometer, are 10 to 20% higher compared to a non-correction (IV) Aerobic contribution of metabolism energy in performing maximal intensity exercises, such as Wingate, more significant in young people, as oxygen uptake kinetics decreases with age in response to high-intensity exercise (V) Use of a fixed applied force, such as 7.5% of mass for cycling, it is not ideal to obtain values of Peak Power and Average Mechanical Power in a test during adolescence, particularly in body composition, as the percentage of muscle and fat concerning body mass varies according to growth and maturation.

The oxidative system has also been shown to play an essential role in maximal protocols both in laboratory tests and in field tests (Glaister, 2005; Spencer et al., 2005; Stone & Kilding, 2009; Tomlin & Wenger, 2001). However, young people have different physiological mechanisms concerning recovery from maximal efforts (Armstrong et al., 2015; Neil Armstrong & Fawkner, 2008; Bergeron et al., 2015; Diry et al., 2020; Falk & Dotan, 2006; Hottenrott et al., 2021; Padulo et al., 2015; Ratel; et al., 2002; Ratel et al., 2002), and there is also sexual dimorphism in this issue (Neil Armstrong & Welsman, 2020; Billaut & Bishop, 2009; Hottenrott et al., 2021). For the consequent interpretation of the data carried out by practitioners and sports scientists, concepts such as peak power (PP), average power (MP) and, fatigue index (FI), where the first two appear as more relevant, however, present data from relatively, it has led to false interpretations, and therefore advanced statistical techniques have been applied by pediatric physiologists (Nevill & Holder, 1995; Tanner, 1949; J. Welsman & Armstrong, 2021; Joanne R Welsman & Armstrong, 2000), with body composition being an increasingly relevant topic in pediatrics (Neil Armstrong & Welsman, 2020; R. M. Malina et al., 2017).

With advancing evidence, especially in the development of aerobic and anaerobic fitness in young athletes (Neil Armstrong & Welsman, 2020), there has been a discussion between study designs and their advantages/disadvantages to inform practice, such as cross-sectional and longitudinal studies (Abarghoueinejad et al., 2021; Neil Armstrong & Welsman, 2020). This study aims to frame the maximal protocol associating itself with size (anthropometric) and body composition, motor, and physiological variables, and thus promote an explanation of the variance in the performance of the Wingate test. In addition, it was hypothesized that biological maturation influences performance in the Wingate test. It was also hypothesized that there might be an inter-association between growth, physical maturation, sports training, and athletic performance factors in young soccer players.

STATE OF THE ART

Match performance: studies in senior and youth soccer

Taking into account the duration of the match, effort in soccer tends to depend from aerobic metabolism, although the intensity approaches 80-90% of HRmax that is considered in the limits of the anaerobic threshold (Stølen et al., 2005). The aerobic and anaerobic contribution is fundamental, and the aerobic is used in lower intensity efforts, in defensive periods, and the anaerobic is recruited in high intensity efforts such as sprint actions (Dolci et al., 2020). A review of the physiology characteristics of senior soccer showed that total distance covered during a game oscillated between 9 and 14 km/h, more than 1400 changes in the activity profile and 700 changes of direction, more than 600 accelerations and 600 deceleration per game, more than 40 high-intensity efforts (speed > 21 km/h) per game, and a 1:12 work/rest ratio between high-intensity activities that changes to 1:2 during intense periods of play (Dolci et al., 2020). High intensity efforts (> 21 km/h) usually do not exceed 31 seconds 20 m in distance, and when performed it is mostly without the ball (Ade et al., 2016). In *Bundesliga*, it was shown that most goal actions preceded a rotation, a linear sprint or change of direction (Faude et al., 2012). In parallel, a study in the *Premier League* showed that high intensity efforts (speed > 21 km/h) was higher in center midfielders (Ade et al., 2016). Among the literature, central back and wing midfielders also evidenced large amounts of high-intensity efforts (Di Salvo et al., 2007).

A systematic review (Palucci Vieira et al., 2019) in young soccer concluded that the ability to perform repeated sprints decreased during the second half. The preceding is considered a sign of acute fatigue (Meckel et al., 2014) as supported by time-motion analysis. Compared to adolescent players, seniors seemed better prepared to perform high-speed running (HSR). In terms of variation by playing position in youth soccer, it was already possible to note that central defenders were less exposed to fatigue induced by HSR, in contrast to midfielders and forwards having a greater exposure.

Other studies using time-motion analysis (Castagna et al., 2003) showed that during the 2nd half, covered distance decreased 5.5% at speeds 13.1-18.0 Km/h. In addition, players stopped 11% of the total played time. Speeds above 18 km/h were performed on 33 sprints with an average time of 2.3±0.6 (intervals: 119±21 sec).

Among under-14, under-16 and under-18, it was shown that the weekly load increased with age (under-14: 2524 ± 128 au; under-16: 2919 ± 136 au; under-18: 3998 ± 222 au). Weekly loads were decreased from under-14 to under-18, and training and game intensity was also lower in under-18 (Wrigley et al., 2012). This probably means that with increasing age, the game becomes more tactical. In a study with 54 young under-17 soccer players, it was possible to observe 96 games defenses (Pettersen & Brenn, 2019). Midfielders covered greater distance of high intensity (1044 m) and a greater sprint distance (224 m) and greater number of accelerations (185). Again, central defenders have lower high-intensity activity, while midfielders reach higher speeds compared to central.
Meantime, subjective indicators such as S-RPE (RPE * training duration) are considered valid methodologies to monitor training (Figueiredo et al., 2021; Marynowicz et al., 2020). Monitoring and individualization of the external training load is increasingly essential due to weekly changes in match performance in young soccer players. Several tools have emerged over time, namely from the Newcastle united academy, when measuring 17 young soccer players and verifying that the countermovement jump, the reactive strength index or some variables of the tri-axial accelerometer (Fitzpatrick et al., 2019). The literature dealing with match performance, training load and S-RPE across an entire season based on representative samples is still lacking.

After assessing 99 soccer players from under-13 to under-18 corresponding to 42 international games, it was concluded that during the first half the younger teams were more likely to perform high-intensity sprints compared to the older teams, and take into account the position and the decrease that occurs in games (Buchheit, Mendez-villanueva, et al., 2010). However, it is not clear if age-associated variation is due to the characteristics of the players, particularly regarding their fitness level or, alternatively, the trend summarizes the progressive tactical approach of elite soccer.

Soccer academies are developing maturation has a central theme to assess young players and to interpret individual data. Maturation has received a great preponderance in soccer academies, and this can influence running performance in young male soccer players, and as such (Parr et al., 2021) in a sample of 37 young soccer players from an English professional academy with under-14, under-15 and under-16 during the 2018-2019 season, where various GPS metrics were associated with biological maturation, however this impact was greater in under-14 compared to under-15/under-16, and young soccer players with advanced maturation were associated with a longer high-speed running distance. A study of 80 players from a premier league academy aged 8-16 years, early maturing players at the transition under-13 / under-14 completed longer distances at high intensity velocity compared to late maturing peers and, additionally, spent higher percentage of time at high intensity (Goto et al., 2019). However, the literature is not consensual, since another study suggested late maturing players as covering longer distances in high-speed running (HSR) and very high-speed running (VHSR) (Lovell et al., 2019).

Maximal intensity protocols to assess fitness level of adolescent soccer players

A longitudinal study of 52 young soccer players aged 11-13 years at baseline (Valente-Dos-Santos et al., 2012) used repeated-sprint ability tests as a valuable sport-specific field test to inform performance level of youth players. The total sprint time of youth soccer players advanced in biological maturation improves more, on average, than that of players who are on time (average) and late in maturation. The performance difference between early and late maturing players is consistent after about 13 years of age. In the same year but with the influence of chronological age and skeletal age, with the same multilevel modeling methodology (Valente-Dos-Santos et al., 2012). Several tests have emerged to be associated with the WanT test to measure anaerobic potency, such as several repeated sprint ability, the running based anaerobic sprint test (RAST) or margaria test, normally used for clinical populations and little for athletic populations. For the soccer population, tests such as the RST and RAST are most mentioned in the literature through association and correlation studies, however studies where the levels of agreement are measured do not exist in abundance in the literature. Additional findings (Girard, Micallef, et al., 2011), with 16 subjects performing the repeated sprint with 12x40 meters and 30 seconds of passive recovery, it was found that the stride frequency decreases with fatigue. The maintenance of high stride frequency, while also maintaining high levels of vertical stiffness, may come to be considered in the near future as a prerequisite for the repeated-sprint ability (RSA).

Wingate Test

The Wingate Anaerobic Test (WAnT) is arguably one of the most famous laboratory fitness tests. It is typically performed on a cycle ergometer and is primarily used to measure an individual's anaerobic capacity and anaerobic power output (Vandewalle et al., 1987).

In its simplest form, this test can be performed using just a Monark or Bodyguard cycle ergometer and a stopwatch (Bar-Or, 1987). As this test only requires the participant to cycle with maximum effort for 30 seconds, its simplicity and time-effectiveness mean that it is an extremely popular testing protocol. Although this test is predominantly performed on a cycle ergometer, it can also be performed on an arm crank ergometer.

Originally based on the Cumming test, this test was developed at the Wingate Institute in Israel during the early 1970's. It has since undergone modifications and has also been used as the basis for designing more recent tests of a similar nature (Tossavainen et al., 1996) and other based protocols. running, such as the Sprint Interval Test (Nummela et al., 1996).

This test has been criticized in different ways and due to several factors such as: (I) the nature of the warm-up, the use of toe clips and heel straps, and whether the test is started from the stationary or continuous start; (II) the periods in which the PP and MP are averaged. For example, PPs averaging 1 s are significantly longer than PPs averaging 5 s, but PPs averaging 3 s or 5 s tend not to be significantly different from each other; (III) Inclusion of flywheel inertia and internal resistance in power calculations. (Chia et al., 1997) demonstrated that 9-year-old PPs and MPs adjusted for cycle ergometer inertia are 10 to 20% greater than PP and MP without this correction; (IV) the aerobic contribution to energy metabolism in performing maximal intensity exercise in the WAnT is greater in young people, as oxygen uptake kinetics decrease with age in response to high-intensity exercise; (V) the use of a fixed applied force, typically 7.5% of body mass for cycling, is not ideal for eliciting PP and MP in a test during childhood and adolescence, particularly as body composition (ex: percentage of muscle and fat in relation to body mass) varies during growth and maturation. (J R Welsman et al., 1997) showed that the use of a single applied force of 0.74 N · kg – 1 of body mass for cycling running with children is not appropriate when comparing the PP and MP of boys and girls, because the Relative applied force used in WAnT, when expressed in relation to thigh muscle volume (TMV), is markedly greater in girls than in boys. Another factor that can affect the results is the sampling rate can significantly affect the accuracy of peak and average power outputs. A Wingate test conducted with computer data feeds with higher sampling rates is shown to be more accurate than tests performed using a standard mechanical ergometer. For the most accurate results, a sampling rate of at least 5 Hz (0.2 seconds) is recommended (Santos et al., 2010).

In a study with 297 young soccer players aged 12.01-20.98, which sought to investigate the development of anaerobic power using age groups and a control group with 29 adults. The Pearson moment correlation coefficient between age and peak power were (r=0.71) and age and mean power (r=0.75). The levels of correlation were high between peak power and body mass (r=0.93) and fat-free mass (r=0.94). In mean power, it was correlated with body mass (r=0.89) and with fat-free mass (r=0.93) (P. Nikolaidis, 2011). These results corroborate previous studies, which show that fat-free mass should be used as a proportion variable (E Doré et al., 2000, 2001; Mercier et al., 1992; P. T. Nikolaidis et al., 2018). With advancing age in young soccer players, fat-free mass appears to be one of the greatest peak power output predictors, and its correlation with age (r=0.68) (P. T. Nikolaidis & Vassilios Karydis, 2011). It is increasingly necessary to assess the anaerobic capacity of young soccer players, as was carried out in a study with 59 American soccer players aged 12.6-16.6 with a diversified battery of tests, including the 30-second wingate test, where the older players showed better peak power output values compared to younger players. The anaerobic capacity must be a characteristic that coaches are increasingly looking at in the processes of identifying and developing talents (Vanderford et al., 2004). Due to these criticisms, tests such as Force-Velocity, on Wingate cycle ergometers, have been conducted in pediatric populations.

Force-Velocity Test

The force-velocity test was developed due to a need for ecological practice of optimizing power output in cycle ergometers (Rudsits et al., 2018). These tests are based on full intensity, often described as "all-out maximal tests". It was first described by (Santos et al., 2002, 2003), where the test consists of a series of 4 to 6 cycles of maximum intensity against various forces applied to the cycle ergometer, ranging from 0.29 to 0.99 N.Kg -1 of body mass. In carrying out the test, the initial force chosen is 0.74 N.kg -1 of body mass and the other forces are applied randomly.

The specifics of these tests consist of a start at 60 rpm with the minimum force applied and ends when the optical sensor of the ergometer detects three consecutive drops in pedal rotations. Each completed sprint is followed by 60 seconds of active recovery at 60 rpm and four minutes of passive recovery before the next sprint.

Reproducibility data, indicated in the literature through the coefficient of variation (CV), show that in a pediatric population there is a variation ranging from

3.5% to 11.9%. However studies in the pediatric population using the limits of agreement are needed.

When analyzing the force-velocity test, there are three variables with a high level of interest, such as: Optimized pedal velocity (Vopt), optimized applied force (Fopt) and optimized peak power (Ppot).

These three variables may undergo some changes that the modification of variables, such as the Vopt, may come to be influenced by the cycle ergometer used. Giving as an example, (C. Williams et al., 2003) that in 3 different cycle ergometers they measured the respective mean Vopt, also including the standard deviation with a load of 0.49 N.kg -1 of the body mass, and respectively in Monark a value of 118 (10), in the SRM isokinetic ergometers a value of 111 (10) and in the Ergomeca cycle a value of 98 (10). All these reported values were analyzed when obtaining the Ppot.

In a study where Vopt was evaluated in different populations (Santos 2002) the following was found: Lower Ppot values in pre-adolescents of both genders (82-90 rpm) compared to the group of adolescents (100-109 rpm) or even in relation to the adult group (105-116 rpm).

However, despite the force-velocity test appearing due to the limitations of the 30-second Wingate (WAnT) test, this also shows its weaknesses as the several described below: (I) to the time required to perform a single 30-s cycle test; (II) a warming or fatigue effect from repeated sprints. This can affect the force-velocity relationships of contracting muscles, which affect the resulting PPopt; (III) the inertia of the steering wheel during acceleration and the internal resistance of the cycle ergometer can influence the PPopt, but no studies with children have addressed these factors; and finally (IV) muscle lactate can be significantly elevated above pre-test concentrations after several sprints. The accumulation of hydrogen ions can have adverse consequences for muscle strength generation and negatively affect Ppopt generation.

Additional findings showed that in the force-velocity test, in a sample of 64 pre-pubertal basketball players, it is necessary to consider the fat-free mass of the whole body, as this shows 53% of variance in this test. It is therefore necessary, when performing the force-velocity test, to interpret the data regarding metabolically active body mass components (Martinho et al., 2021).

Determinants of performance in short-term maximal intensity (all-out) output

Studies performed on cycle ergometers have been the most performed in decades (Van Praagh & Doré, 2002) and differences between chronological ages have been associated with neuromuscular factors, hormonal factors and motor coordination . Studies carried out over the years have emerged in cross-sectional or longitudinal design. Cross-sectional studies carried out in the athletic population refer to the basketball modality, where the relationship between growth, maturation and short-term power output was studied (Carvalho, Coelho E Silva, et al., 2011) in 94 basketball players aged between 14 and 16 years, and the main predictors of short-term power output were skeletal maturation, body mass and lower limb length, that is, it is necessary to consider maturation, not be seen as a confounding factor, in the assessment of short-term power output. However, there is a high variation associated with performance, and a study of 93 basketball players between 14- and 16-years old shows that peak power and mean power values increase linearly close to peak height velocity and suggests future studies with allometric scaling to verify factors preponderant (Carvalho, Coelho-e-Silva, et al., 2011).

Longitudinal studies conducted in UK has pioneered the use of advanced statistical techniques with allometric scalling and multilevel modeling. Two studies deserves to be mentioned. The first study examined the development of peak power and mean power on two different ergometers with 135 young people. The state of maturation was assessed through the pubic hair stages revealed by (Tanner, 1962). In this same study, it was found that short-term power development is greater in boys than in girls, and the greatest morphological predictor is lean mass, and PP and MP values differ from ergometer to ergometer (Neil Armstrong et al., 2019).

In the second study, to assess short-term power output in relation to sex and concurrent changes in age, body mass, fat-free mass, and maturation status, in 388 young people aged 11 to 18 years. Again, it is shown that short-term power output is higher in boys than in girls, and the predictors influencing short-term power output are concurrent changes in age and fat-free mass (Neil Armstrong & Welsman, 2019).

CHAPTER II - METHODOLOGY

Procedures

The current study received ethical approval from the competent committee of the *University of Coimbra* (CE/FCDEF-UC/00122014). Procedures were conducted according to the standards established by the declaration of Helsinki and guidelines (Harriss et al., 2019). Legal guardians were informed about the nature of the study, including objectives, protocol and related risks, and signed informed consent. The same observers completed measurements under the same conditions at *Coimbra University Stadium*. When visiting the laboratory, adolescent players were informed that their participation was voluntary, and all provided consent after being informed that they could withdraw from the study at any time.

Participants

The current study recruited a cross-sectional sample. The sample size matches the calculations obtained from G*Power software (v3.1.9.2, University of Kiel, Germany). Previous studies reported significant associations among 93 male adolescents of other sports, such as basketball players aged 14-16 years, who were also assessed to obtain Wingate test outputs and body size descriptors about CA and somatic maturation (Carvalho, Coelho-e-Silva, et al., 2011). The present sample was composed of 89 male adolescent soccer players aged 14-15 who competed in several clubs from the Portuguese Midlands (regions of Aveiro and Coimbra). Considering the previous information, the number of participants in the current study should be regarded as satisfactory. The organization of youth soccer in Portugal adopts a 2-year age group. Accordingly, players aged 13-14 years were classified as initiates. Long-term participation in youth soccer considers the following age groups: infantiles (11-12 years), initiates (13-14 years), juveniles (15-16 years), and juniors (17-18 years). Information regarding training experience and the playing position was obtained from each player and checked by club records.

The initiates in the current study experienced participation in the sport from 2 to 7 years. In general, clubs participated in a 9-month competitive season (September/May) organized by the Portuguese Soccer Federation. Players completed 3-5 training sessions per week (about 90-120 min) and one game per week, usually on Saturday.

Anthropometry

A single and experienced observer collected the anthropometry data following standardized procedures (Lohman et al., 1988). First, stature and sitting height were measured to the nearest 0.1 cm using, respectively, a Harpenden stadiometer (model 98.603, Holtain Ltd., Crosswell, UK) and Harpenden sitting height table (Harpenden, Holtain LTD, Crosswell, UK). Subsequently, leg length was calculated as stature minus sitting height. Body mass to the nearest 0.1 kg using a SECA balance (model 770, Hanover, MD, USA).

Somatic Maturation

Chronological age, stature and body of the participants and mid-parent stature were used to estimate adult stature with the protocol developed on the sample of the Fels Longitudinal Study (Khamis & Roche, 1994). The current stature of each player was expressed as a percentage of their predicted mature stature (PMS) as an estimate of biological maturation at the time of measurement. Subsequently, percentages of PMS were expressed as z-scores relative to age-specific means and standard deviations for the percentage of mature height attained at half-yearly intervals by boys in the Berkeley Guidance Study, University of California (Bayer & Bayley, 1959). Corresponding data were not available for a European sample. The z-scores were used to estimate maturity status: on time, z-score between -1.0 and +1.0; late, z-score below -1.0; early, z-score above +1.0.

Air displacement plethysmography (ADP)

Body volume was derived from air-displacement plethysmography (Bod Pod Body Composition System, model Bod Pod 2006, Life Measurement, Inc, Concord, CA, USA). Participants were assessed using lycra underwear and a swim cap as recommended by the manufacturer. Before each trial, the equipment was calibrated using a 2-point assessment method using a 50.255-L cylinder and following the manufacturer's instructions. Each individual was seated in the chamber while the natural body volume was consecutively measured until two consecutive values within 150 mL were obtained. If more than three natural body volumes were necessary, additional measurements were obtained after recalibration. Body density was calculated as body mass (kg) divided by body volume (L) and was used to calculate the percentage of fat mass using the equation proposed for children and youth by (Lohman et al., 1988).

Performance (WAnT)

Each participant completed a standardized 4-min warm-up on the cycle-ergometer (Monark 894 Peak Bike, Monark AB, Varberg, Sweden), including three maximal sprints for 3–4 s at the end of each minute. Static stretches of the quadriceps, hamstring, and abductors muscles were performed under supervision before the Wingate test (WAnT). The 30-s WAnT requires the calculation of a standardized resistance (7.5% of body mass) and is described elsewhere (Driss & Vandewalle, 2013). The protocol started after a verbal signal (3-2-1-Go) with the participant pedaling at 60 rpm (revolutions per minute). The braking force was automatically applied when 70 rpm was exceeded. The adolescent players were seated during maximal intensity effort and used toe clips. They received standardized verbal encouragement. The ergometer used a sampling rate of 50 Hz. Performance outputs were extracted (in watts) using Anaerobic Test Software (Monark Exercise AB, Vansbro, Sweden). The following parameters were retained for analysis: WAnT-PP (peak power corresponding to the highest value observed during the initial 10 s) and WAnT-MP (mean power defined as the average performance during the test).

Jumping performance

The vertical jump test assessed lower limb explosive power (Bosco et al., 1983). This protocol includes squat jumps (SJ) and countermovement jumps (CMJ). The first consisted of maximal voluntary jump action from a fixed semi-squat position with the hands held at the hips. In the CMJ, players were instructed to keep their hands on the hips from the starting position through the countermovement (phase, jump, and flight trajectory. The protocols required a platform (Ergojump; Globus, Codogné, Italy) to measure flight time, and jumping height was assessed from flight time and body mass. Three trials were performed for both tests with a two-minute interval between jumps and the best jump height (cm) retained for subsequent analysis.

Analysis

Descriptive statistics (minimum, maximum, mean, standard error of the mean, 95% confidence limits of the mean, and standard deviation) were computed for the total sample. Subsequently, bivariate correlation coefficients were determined between functional parameters and chronological age, attained % PMS (attained predicted mature stature in %), Z-score of % PMS using mean and standard deviation for the percentage of mature height attained at half-yearly intervals by boys in the Berkeley Guidance Study, University of California (Bayer & Bayley, 1959). Analysis of variance was used to test the effect of playing position considering the following categories: goalkeepers, defenders, midfielders, and forwards). The significance level was established at 5%. Additionally, the magnitude effect given by d-cohen values (Cohen, 1992) was used to examine mean differences between goalkeepers and outfield players and mean differences between defenders *versus* midfielders, defenders *versus* forwards, and midfielders *versus* midfielders forwards. The magnitude of d-value was interpreted as follows (William G Hopkins et al., 2009): <0.20 (trivial); 0.20 to 0.59 (small); 0.60 to 1.19 (moderate); 1.20 to 1.99 (large); 2.00 to 3.99 (very large); ≥4.00 (extremely large). Analyses were performed using the Statistical Package for the Social Sciences - SPSS for Windows (version 27, SPSS Inc., IBM Company, Armonk, NY, USA).

CHAPTER III - RESULTS

Table I summarizes the descriptive statistics for all variables. In addition, Table II evidenced bivariate correlation coefficients between chronological age, an indicator of timing regarding biological maturation (percentage of predicted mature stature), and an indicator of tempo (z-scores of the attained percentage of predicted mature stature. The current sample ranged 84.7% to 97.5% for % PMS and fluctuated between -0.86 and +1-79 z-scores for %PMS using the sex- and age-specific means and standard deviations obtained at Berkeley Guidance Study. Chronological age is positively correlated with body mass (0.502), fat-free mass (r=0.549) and, in parallel with WAnT outputs (peak: 0.558; mean: 0.519).

Table 1. Descriptive statistics for chronological age, years of training, somatic maturation, body size assessed by air displacement plethysmography, Wingate outputs, and jumping performance among adolescent soccer players aged 13-14 years (n=89)

Variable	units	Range		mean				standard deviation
		minimum	Maximum	value	Standard error	95% CL		
						lower	upper	
Chronological age	year	13.07	14.97	14.19	0.50	14.09	14.30	0.50
Training experience	year	2.0	7.0	5.2	0.1	5.0	5.3	1.0
Attained PMS	%	84.7	97.5	93.43	0.29	92.85	94.01	2.76
PMS Z-score		–0.86	1.79	0.72	0.06	0.61	0.83	0.53
Stature	Cm	142.1	186.6	167.2	1.0	165.2	169.2	9.3
Body mass	Kg	34.800	91.500	55.511	1.084	53.353	57.851	10.222
Estimated thigh volume	L	2.59	8.10	4.21	0.11	3.99	4.43	1.01
Body volume	L	32.492	86.050	52.021	1.003	50.023	54.197	9.463
Thoracic gas volume	L	1.808	4.471	3.086	0.606	2.970	3.212	0.572
Body density	Kg.L	1.042	1.086	1.07	0.001	1.07	1.07	0.01
Fat mass	%	2.9	22.5	10.3	0.4	9.4	11.2	4.2
Fat-free mass	Kg	30.1	79.1	50.0	1.0	48.0	52.1	9.9
WAnT: peak output	watt	342	1213	717	19	680	755	180
	watt.Kg	7.75	17.33	12.83	0.18	12.48	176.25	24.22
	watt.L	103	254	171	2.57	166	176	24
WAnT: mean output	watt	278	770	476	11	454	498	104
	watt.Kg	6.66	11.74	8.54	0.07	8.39	8.69	0.69
	watt.L	87	180	114	1.52	111	117	14
Squat Jump	Cm	17.5	38.2	27.9	0.5	27.0	28.8	4.3
Countermovement Jump	cm	22.6	42.8	31.2	0.5	30.3	32.1	4.2

PMS (predicted mature stature); PMS Z-score (attained predicted mature stature in % transformed into Z-score based on mean and standard deviation for boys in the University of California at Berkeley Guidance Study – *see methods*); WAnT (Wingate); 95%CL (95% confident limits)

The indicator of maturational timing (attained %PMS) seemed to present larger coefficients with body size descriptors than the maturational tempo indicator (z-scores of %PMS). For whole-body size descriptors and appendicular volume, correlation coefficients were large for body mass and estimated thigh volume, respectively, 0.659 and 0.556, and very large for stature (0.725). In terms of performance variables, jumping outputs did not correlate with chronological age or biological maturation indicators. The WAnT outputs showed large to very large correlation coefficients with %PMS (peak: 0.677; mean: 0.703). The correlation between WAnT and z-scores of %PMS is no more than moderate.

Table 2. Bivariate correlation among chronological age, attained % PMS, Z-score of % PMS and morphology and functional parameters among male adolescent soccer players aged 13-14 years (n=89)

	Chronological age		Attained % PMS		% PMS (Z-score)	
	r	(95% CL)	r	(95% CL)	r	(95% CL)
Stature	0.433	(0.255; 0.577)	0.725	(0.605; 0.810)	0.604	(0.447; 0.715)
Body mass	0.502	(0.343; 0.642)	0.659	(0.530; 0.777)	0.450	(0.277; 0.589)
Estimated thigh volume	0.450	(0.256; 0.619)	0.556	(0.428; 0.692)	0.345	(0.188; 0.507)
Fat mass	–0.398	(–0.543; -0.219)	–0.512	(–0.658; -0.327)	–0.350	(–0.516; -0.139)
Fat mass	–0.128	(–0.337; 0.067)	–0.152	(–0.371; 0.057)	–0.095	(–0.268; 0.100)
Fat-free mass	0.549	(0.390; 0.685)	0.720	(0.611; 0.823)	0.489	(0.316; 0.627)
WAnT Peak (watt)	0.558	(0.408; 0.690)	0.677	(0.566; 0.784)	0.416	(0.233; 0.575)
WAnT Peak (watt.Kg^{-1})	0.405	(0.248; 0.552)	0.436	(0.277; 0.587)	0.215	(0.003; 0.412)
WAnT Peak (watt.L^{-1})	0.263	(0.084; 0.417)	0.320	(0.125; 0.523)	0.206	(–0.021; 0.406)
WAnT mean (watt)	0.519	(0.357; 0.655)	0.703	(0.590; 0.801)	0.493	(0.327; 0.626)
WAnT mean (watt.Kg^{-1})	0.293	(0.137; 0.464)	0.450	(0.322; 0.600)	0.349	(0.184; 0.524)
WAnT mean (watt.L^{-1})	0.073	(–0.143; 0.241)	0.203	(0.011; 0.389)	0.236	(0.007; 0.450)
Squat jump	0.166	(–0.036; 0.375)	0.266	(0.120; 0.424)	0.140	(-0.023; 0.310)
Countermovement Jump	0.229	(0.014; 0.417)	0.309	(0.150; 0.470)	0.154	(0.001; 0.302)

%PMS (percentage of predicted mature stature); Z-score (Based on the mean and standard deviation for boys in the *University of California* at *Berkeley Guidance Study – see methods*).

In conclusion, the relative values for anaerobic performance expressed in watt per kg of body mass and watt per L of estimated thigh volume tended to present correlation coefficients interpreted as small or moderate. The comparison between groups contrasting in the tempo of biological maturation given by z-scores of %PMS did not differ for chronological age nor training experience. As expected, participants above the median, that is, the adolescent soccer players who tended to be advanced in terms of somatic maturation were taller ($t=4.415$, $p<0.01$, $d=0.89$), heavier ($t=3.306$, $p<0.01$, $d=0.71$) and were characterized by larger thigh volume ($t=2.935$, $p>0.01$, $d=0.64$) and fat-free mass expressed in kg ($t=3.539$, $p<0.01$, $d=0.76$). The two groups differed in WAnT outputs expressed in watt (peak: $t=3.308$, $p<0.01$, $d=0.65$; mean: $t=3.654$, $p<0.01$, $d=0.78$). Male adolescent soccer players above the median in terms of z-scores for PMS always obtained better scores in the anaerobic protocol adopted in the present study. However, the differences were attenuated when WAnT outputs were expressed in watt per unit of body mass or watt per L of estimated thigh volume and tended to be not significant. For jumping performances, participants who were more likely to be advanced attained better mean scores: +1.3 cm in the squat jump (not significant) and 1.8 cm in the countermovement jump ($t=1.99$, $p<0.05$, $d=0.43$).

Table 3. Descriptive statistics (mean ± standard deviation) by groups contrasting in somatic maturation‡ among male adolescent soccer players aged 13-14 years (n=89) and comparison between groups on chronological age, training experience, morphology, and functional outputs.

Dependent variable	units	Attained % of predicted mature stature (z-scores) G1 (< median)	Attained % of predicted mature stature (z-scores) G2 (> median)	mean difference (95% CL)	comparison: t-test t-value	comparison: t-test p	comparison: magnitude effect d	comparison: magnitude effect (qualitative)
Chronological age	year	14.20 ± 0.49	14.19 ± 0.52	0.02 (−0.20; 0.23)	0.147	0.884	0.02	(trivial)
Training experience	year	5.3 ± 0.8	5.1 ± 1.1	0.2 (−0.2; 0.6)	1.097	0.276	0.21	(small)
% PMS	%	92.0 ± 2.8	94.9 ± 1.8					
Stature	cm	163.5 ± 8.9	171.0 ± 8.2	−7.5 (−11.1; −3.9)	−4.415	0.000	0.89	(moderate)
Body mass	Kg	52.2 ± 8.9	59.0 ± 10.5	−6.8 (−10.9; −2.7)	−3.306	0.001	0.71	(moderate)
Estimated thigh volume	L	3.91±0.77	4.52±1.14	−0.61 (−1.02; −0.20)	−2.935	0.004	0.64	(moderate)
Fat mass	%	11.1 ± 5.0	9.5 ± 3.0	1.6 (−0.1; 3.4)	1.886	0.063	0.41	(small)
Fat mass	Kg	5.7 ± 2.5	5.6 ± 1.9	0.1 (−0.8; 1.1)	0.260	0.795	0.06	(trivial)
Fat-free mass	Kg	46.6 ± 8.9	53.5 ± 9.6	−7.0 (−10.9; −3.0)	−3.539	0.001	0.76	(moderate)
WAnT: peak output	watt	663 ± 168	773 ± 176	−110 (−183; −38)	−3.028	0.003	0.65	(moderate)
	Watt. Kg	12.61 ± 1.85	13.06 ± 1.41	−0.45 (−1.14; 0.25)	−1.281	0.203	0.28	(small)
	Watt. L	169.5 ± 28.3	172.9 ± 19.4	−3.4 (−13.7; 6.8)	−0.665	0.508	0.14	(trivial)
WAnT: mean output	watt	439 ± 94	514 ± 100	−75 (−116; −34)	−3.654	0.000	0.78	(moderate)
	watt. Kg	8.38 ± 0.80	8.70 ± 0.51	−0.33 (−0.61; −0.04)	−2.284	0.025	0.48	(small)
	Watt. L	112.8 ± 16.5	115.6 ± 11.7	−2.8 (−8.8; 3.3)	−0.904	0.368	0.19	(trivial)
Squat Jump	cm	27.3 ± 4.4	28.6 ± 4.2	−1.3 (−3.1; 0.5)	−1.406	0.163	0.30	(small)
Countermovement Jump	cm	30.3 ± 4.2	32.1± 4.1	−1.8 (−3.5; −0.0)	−1.999	0.049	0.43	(small)

%PMS (attained predicted mature stature in %); PMS (predicted mature stature); WAnT (Wingate test); 95% CL (95% confidence limits); t-value (derived from independent t-test); d (value of d-cohen); ‡ somatic maturity status derived from Z-score of % PMS using mean and standard deviation obtained from Berkeley Guidance Study (see methods).

Finally, considering the four categories as presented in Table IV, the dependent variables that seemed to be affected by specialization into playing positions were stature ($F=3.791$, $p<0.01$; ES-r=0.344), body mass ($F=4.299$, $p<0.01$; ES-r=0.363), estimated thigh volume ($F=4.098$, $p<0.01$; ES-r=0.350), fat-free mass in kg ($F=3.562$, $p<0.05$; ES-r=0.334) and WAnT mean output when expressed per unit of body mass ($F=3.461$, $p<0.05$; ES-r=0.330) or per L of estimated thigh volume ($F=4.115$, $p<0.01$; ES-r=0.356).

Lastly, the multiple comparisons between playing positions were determined for goalkeepers versus outfield players with moderate differences diagnosed for training experience ($d=1.16$) and countermovement ($d=0.74$) with goalkeepers with more training experience poorer jumping performances in the countermovement jump. Between outfield players, defenders presented mean differences of moderate magnitude when compared to midfielders for stature ($d=0.77$), body mass ($d=0.64$), estimated thigh volume ($d=0.79$), WAnT in watt per L of thigh volume (peak: $d=0.70$; mean: $d=0.94$). Defenders were larger for all body size descriptors and poorer in functional above-mentioned functional WAnT parameters. The trend between defenders and forwards is similar to the previously described for defenders and midfielders. In contrast, the mean differences between midfielders and forwards were negligible at the ages covered in the present study.

Table 4. Descriptive statistics (mean ± standard deviation) by playing position and results of ANOVA including magnitude effects between groups

Dependent variable	units	Playing position				F	p	ES-r	d-cohen			
									GK vs. Outfield players	Outfield players		
		Goalkeeper (n=8)	Defender (n=33)	Midfielder (n=20)	Forwards (n=28)					Def *vs.* Mid	Def *vs.* For	Mid *vs.* For
Chronological age	year	14.10± 0.53	14.23±0.49	14.15±0.57	14.22±0.47	0.190	0.903	0.082	0.22	0.16	0.02	0.14
Training experience	year	6.1±0.4	5.0±1.1	5.1±0.7	5.1±0.9	3.398	0.021	0.327	1.16	0.11	0.10	0.00
% PMS	%	94.4±1.3	93.7±2.9	92.7±2.7	93.3±2.9	0.874	0.458	0.173	0.41	0.36	0.14	0.22
Stature	cm	171.7±5.3	170.3±10.6	163.3±6.4	165.1±9.0	3.791	0.013	0.344	0.55	0.77	0.53	0.23
Body mass	Kg	59.4±6.0	59.5±12.1	52.9±6.8	51.6±8.9	4.299	0.007	0.363	0.43	0.64	0.64	0.16
Estimated thigh volume	L	4.24±0.56	4.66±1.21	3.84±0.72	3.94±0.87	4.098	0.009	0.350	0.03	0.79	0.69	0.13
Fat mass	%	9.1±4.0	10.6±4.3	10.2±4.2	10.2±4.2	0.273	0.845	0.098	0.31	0.10	0.10	0.00
Fat mass	Kg	5.3±2.2	6.2±2.5	5.4±2.2	5.1±1.8	1.470	0.228	0.222	0.14	0.34	0,51	0.16
Fat-free mass	Kg	54.3±7.0	53.3±11.4	47.8±7.0	46.5±9.0	3.562	0.018	0.334	0.49	0.56	0.67	0.16
WAnT: peak output	Watt	758±86	766±220	693±168	666±140	1.870	0.141	0.249	0.25	0.37	0.54	0.18
	Watt. Kg	12.81±1.34	12.71±1.85	12.96±1.96	12.89±1.29	0.116	0.950	0.064	0.01	0.13	0.11	0.04
	Watt. L	181±25	164±22	181±29	171±21	2.630	0.055	0.291	0.44	0.70	0.33	0.41
WAnT: mean output	Watt	469±48	510±119	470±96	442.0±93.4	2.289	0.084	0.273	0.08	0.37	0.64	0.30
	Watt. Kg	7.93±0.76	8.53±0.59	8.82±0.88	8.53±0.53	3.461	0.020	0.330	1.01	0.42	0.00	0.43
	Watt. L	112±16	110±10	123±19	113.0±11.9	4.115	0.009	0.356	0.18	0.94	0.28	0.67
Squat Jump	cm	26.6±3.6	29.0±4.3	26.4±5.0	28.1±3.8	1.887	0.138	0.250	0.33	0.58	0.22	0.40
Countermovement jump	cm	28.4±3.0	32.1±4.3	31.2±5.4	30.9±3.2	1.721	0.169	0.239	0.74	0.19	0.32	0.07

ANOVA (analysis of variance); %PMS (attained predicted mature stature in %); WAnT (Wingate test); GK (goalkeeper); Def (defender); Mid (midfielder); For (forwards).

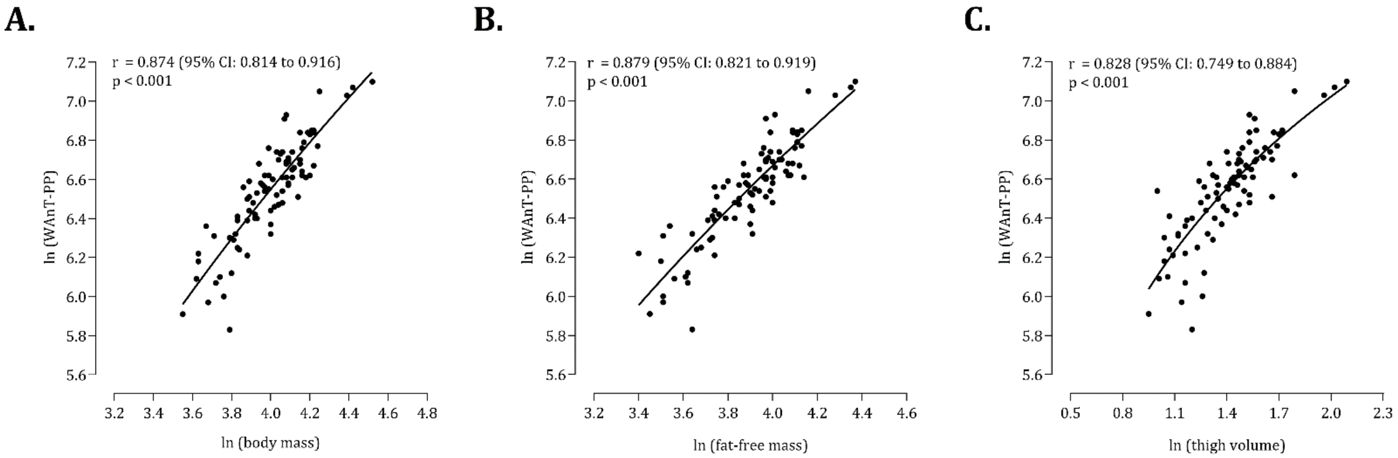

Figure 1. Correlation between WAnT peak power and body mass, fat-free mass and thigh volume.

Figure 1 represents the correlations between peak power and body mass (A) and fat-free mass (B) and thigh appendicular volume (C). Confidence intervals ranged between 0.749 and 0.919, and all correlations are statistically significant ($p<0.001$).

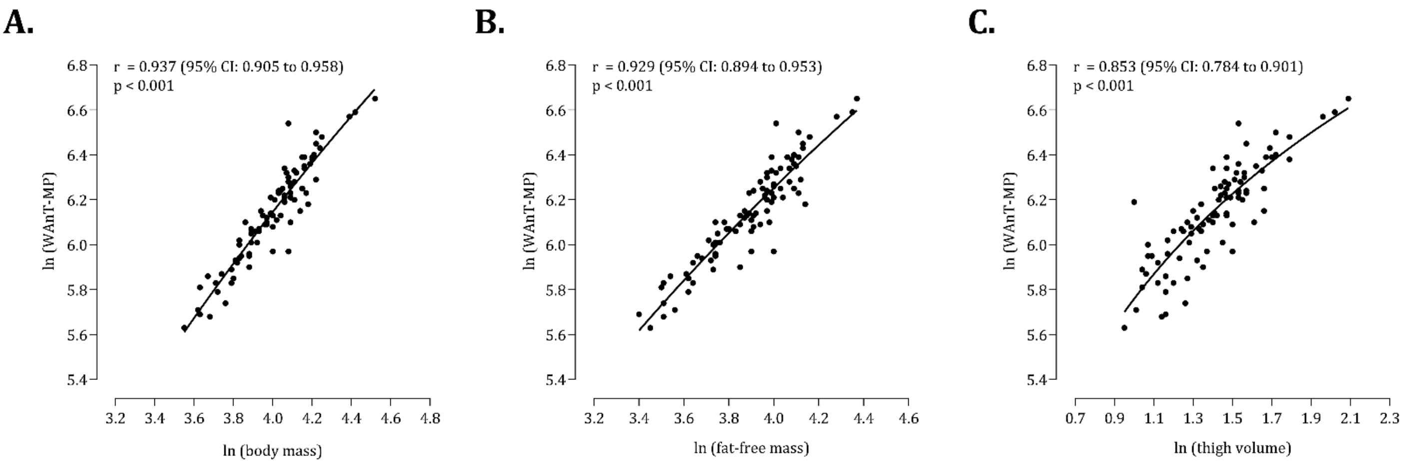

Figure 2. Correlation between WAnT mean power and body mass, fat-free mass and thigh volume.

Figure 2 represents the correlations between mean power and body mass (A) and fat-free mass (B) and thigh appendicular volume (C). Confidence intervals ranged between 0.784 and 0.958, and all correlations are statistically significant ($p<0.001$).

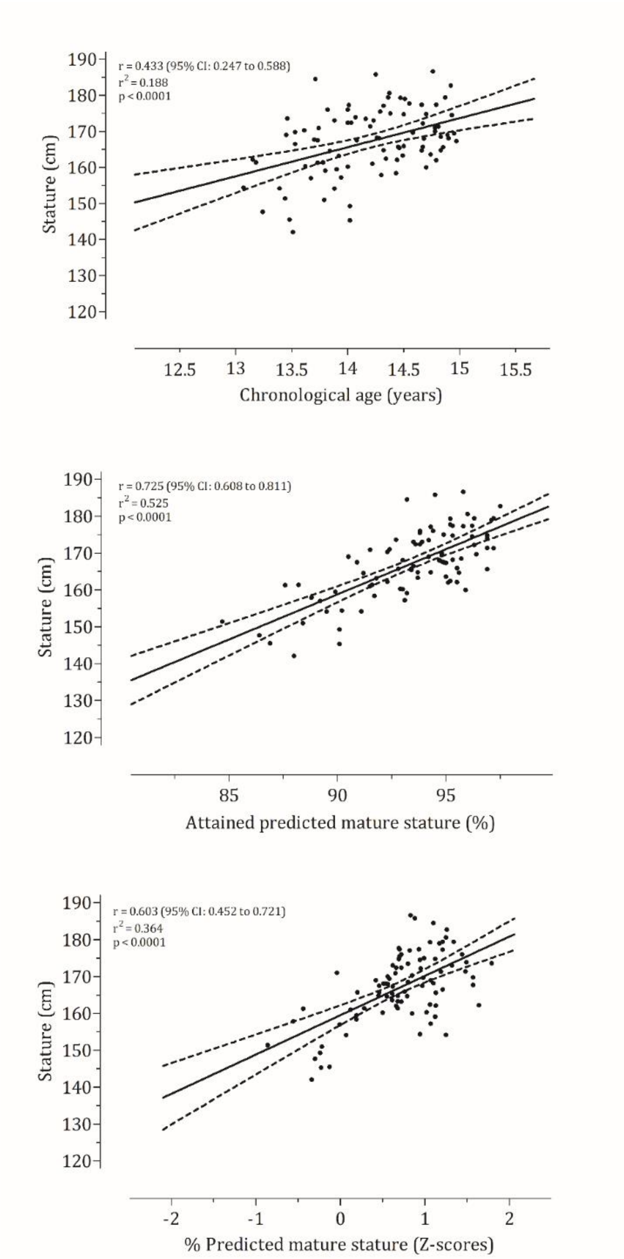

Figure 5. Correlation between stature and chronological age, attained predicted mature stature (%) and % predicted mature stature (z-scores).

Figure 3 represents the correlations between stature and chronological age (A) and attained predicted mature stature (B) and % predicted mature stature (z-scores) (C). Confidence intervals ranged between 0.247 and 0.811, and the correlation of (B) (r=0.725) is strong while that of (C) (r=0.603) is moderate.

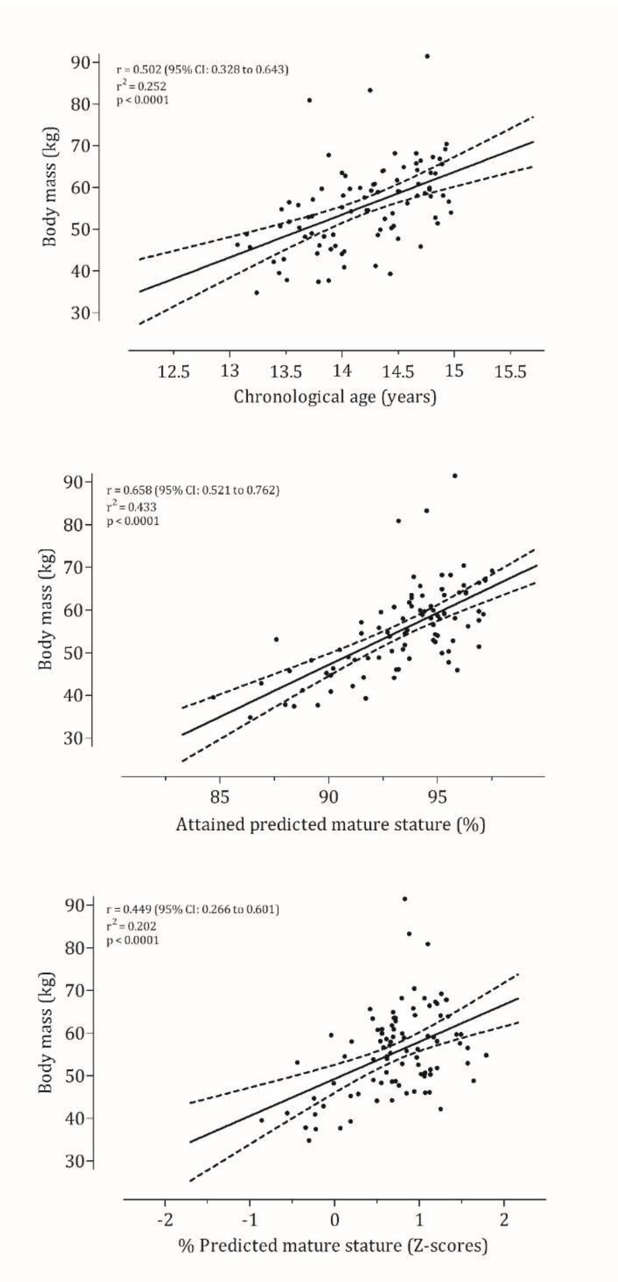

Figure 6. Correlation between body mass and chronological age, attained predicted mature stature (%) and % predicted mature stature (z-scores).

Figure 4 represents the correlations between body mass and chronological age (A) and attained predicted mature stature (B) and % predicted mature stature (z-scores) (C). Confidence intervals ranged between 0.266 and 0.762, and the correlations of (A) (r=0.502) and (B) (r=0.658) are moderate.

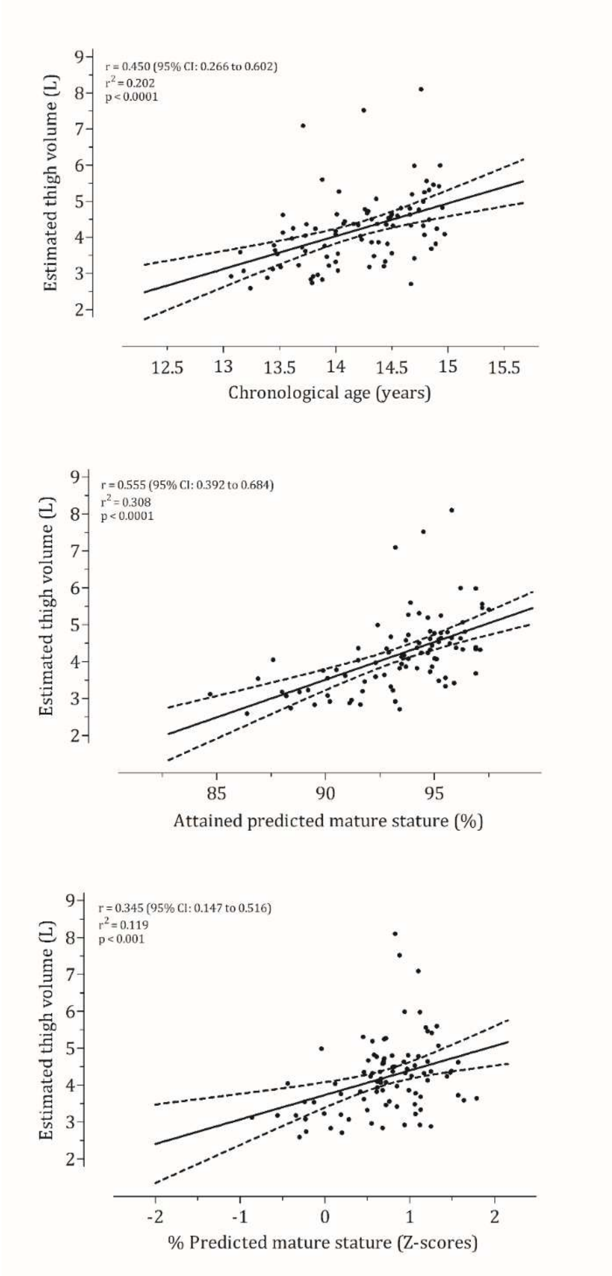

Figure 7. Correlation between Estimated thigh volume and chronological age, attained predicted mature stature (%) and % predicted mature stature (z-scores).

Figure 5 represents the correlations between Estimated thigh volume and chronological age (A) and attained predicted mature stature (B) and % predicted mature stature (z-scores) (C). Confidence intervals ranged between 0.147 and 0.684, and the correlation of (B) (r=0.555) is moderate.

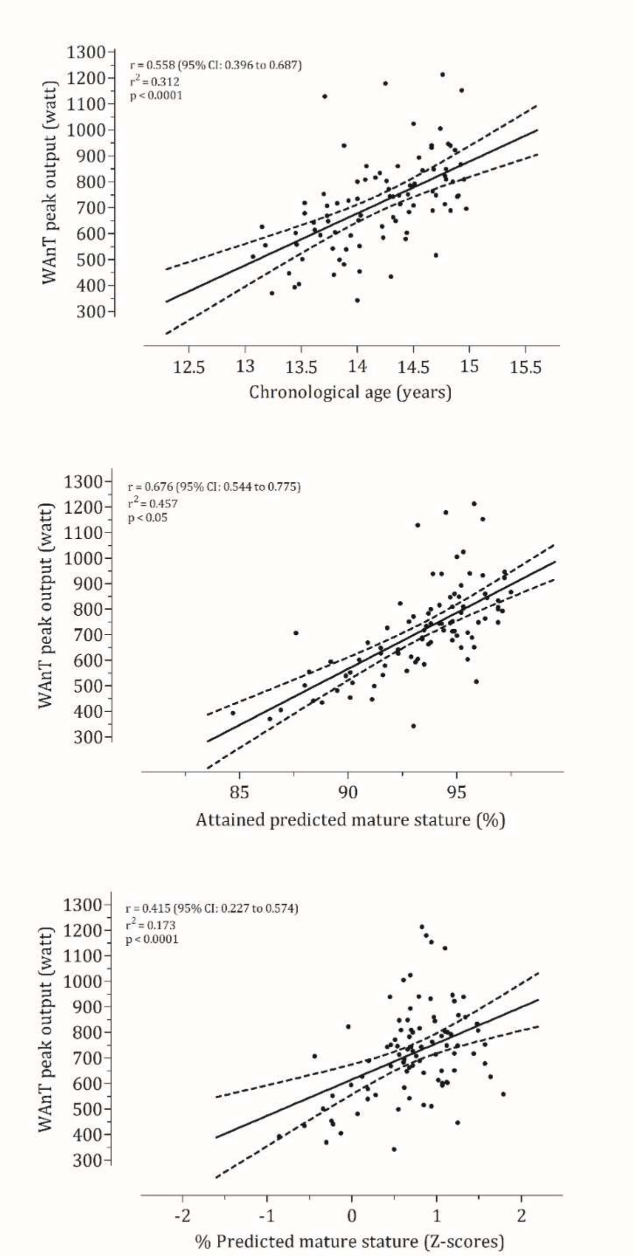

Figure 8. Correlation between WAnT peak output and chronological age, attained predicted mature stature (%) and % predicted mature stature (z-scores).

Figure 6 represents the correlations between WAnT peak output (watt) and chronological age (A) and attained predicted mature stature (B) and % predicted mature stature (z-scores) (C). Confidence intervals ranged between 0.227 and 0.775, and the correlations of (A) (r=0.558) and (B) (r=0.676) are moderate.

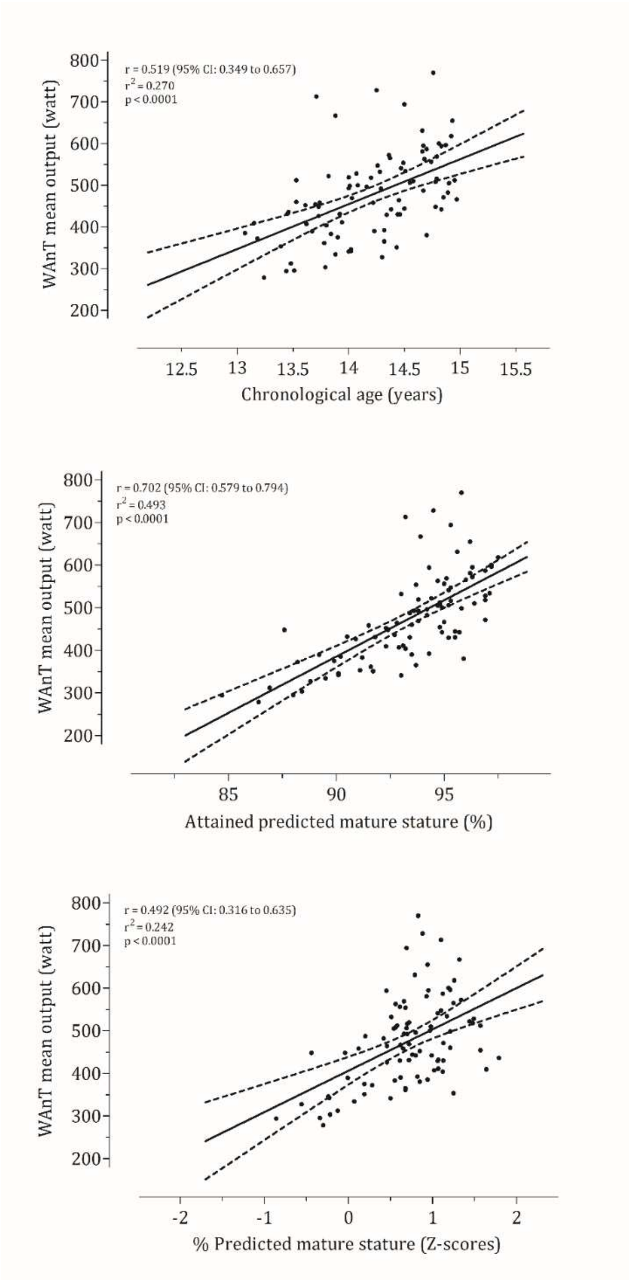

Figure 9. Correlation between WAnT mean output and chronological age, attained predicted mature stature (%) and % predicted mature stature (z-scores).

Figure 7 represents the correlations between WAnT mean output (watt) and chronological age (A) and attained predicted mature stature (B) and % predicted mature stature (z-scores) (C). Confidence intervals ranged between 0.316 and 0.794, and the correlation of (A) (r=0.519) is moderate and (B) (r=0.702) is strong.

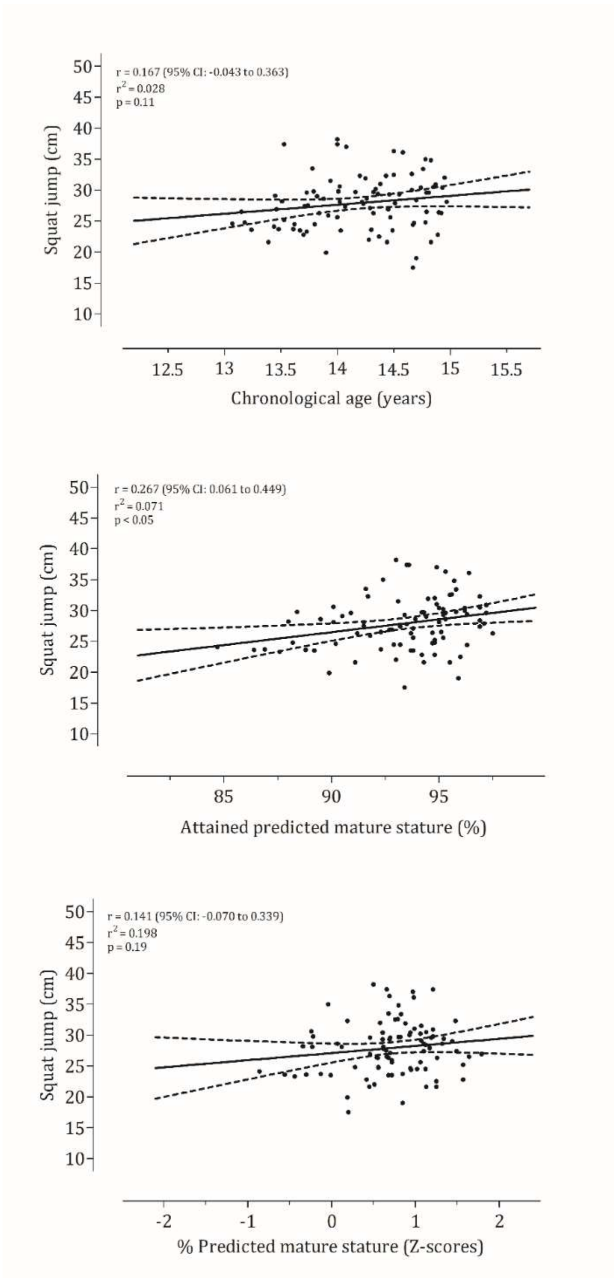

Figure 10. Correlation between squat jump and chronological age, attained predicted mature stature (%) and % predicted mature stature (z-scores).

Figure 8 represents the correlations between Squat jump (cm) and chronological age (A) and attained predicted mature stature (B) and % predicted mature stature (z-scores) (C). Confidence intervals ranged between -0.043 and 0.449, and the correlations of (A), (B), and (C) are negligible.

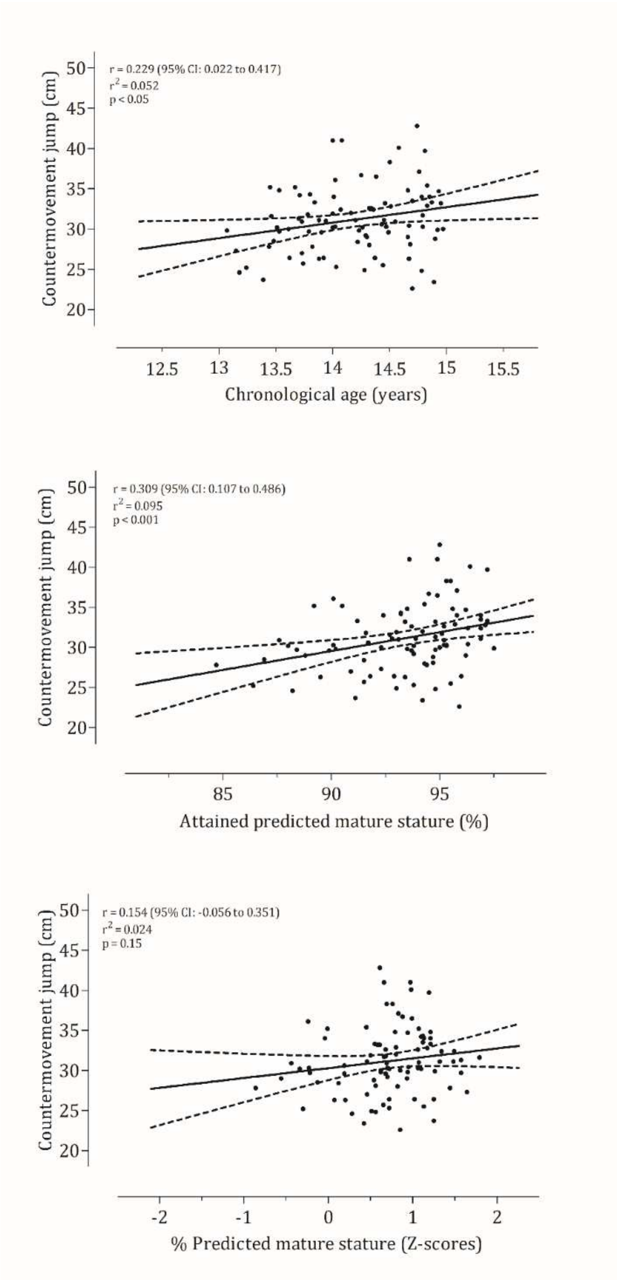

Figure 11. Correlation between countermovement jump and chronological age, attained predicted mature stature (%) and % predicted mature stature (z-scores).

Figure 9 represents the correlations between Countermovement jump (cm) and chronological age (A) and attained predicted mature stature (B) and % predicted mature stature (z-scores) (C). Confidence intervals ranged between 0.022 and 0.486, and the correlation of (B) is weak (r=0.309).

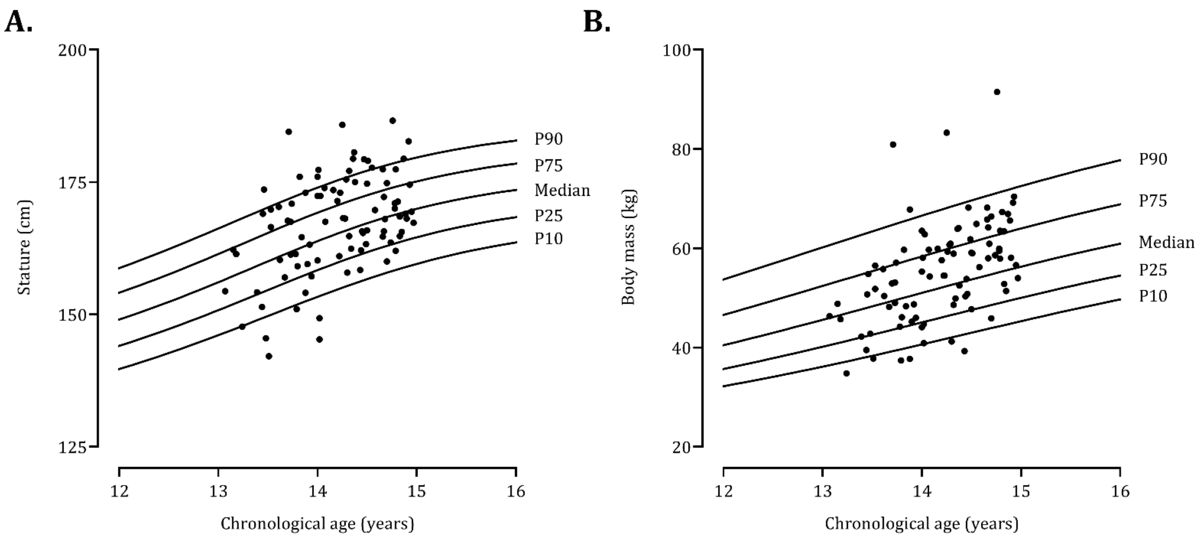

Figure 12. Growth charts individual stature for chronological age and individual body mass for chronological age.

In this sample, the vast majority of young soccer players are between the 10th and the 90th percentile, either in stature or body mass, about chronological age, individually (Figure 10).

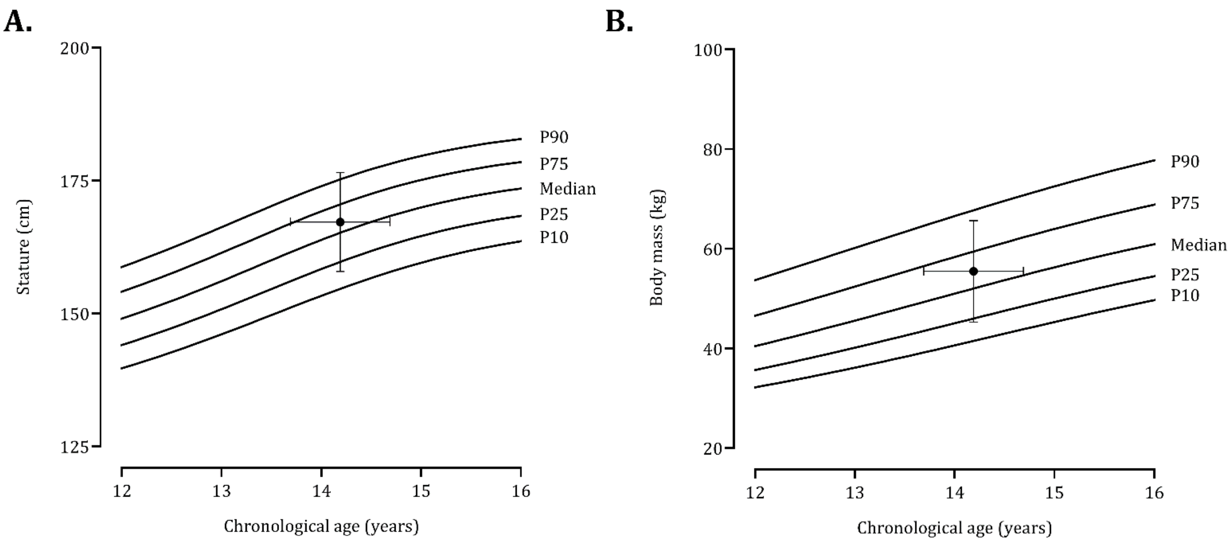

Figure 13. Growth charts mean stature for chronological age and mean body mass for chronological age.

In the analysis of the mean, the sample of this study, in terms of stature and body mass with chronological age, is found between the mean and the 75th percentile (Figure 11).

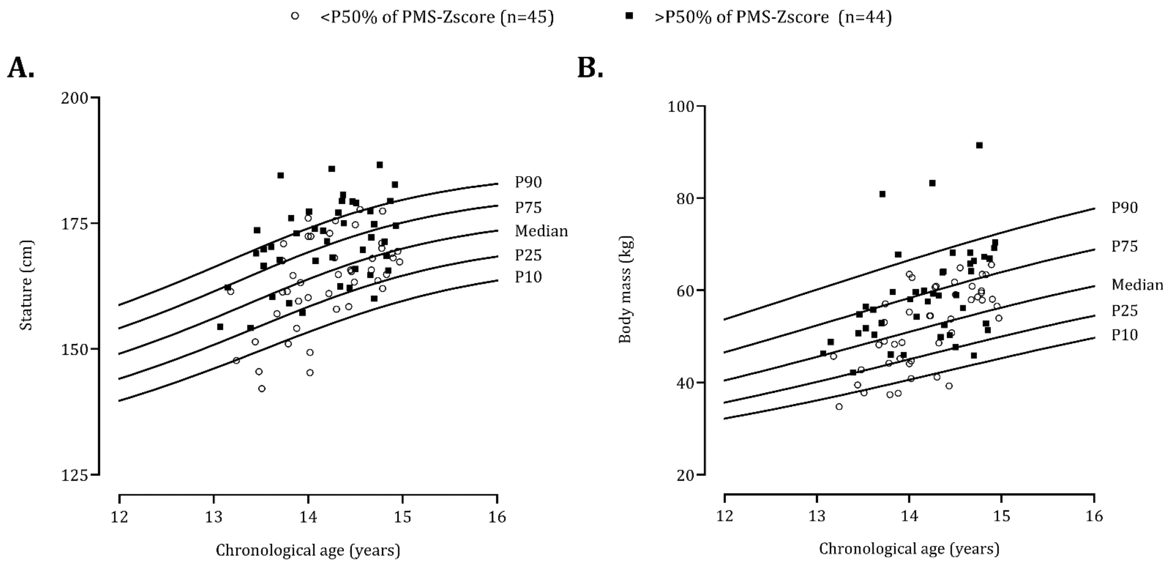

Figure 15. Growth charts individual by PMS z-score stature for chronological age and individual by PMS z-score body mass for chronological age.

In the analysis by z-scores by PMS, in the graph of stature by chronological age, the group below 50% tends to have individuals below the 10th percentile. Conversely, the group above 50% tends to exceed the 90th percentile (Figure 12).

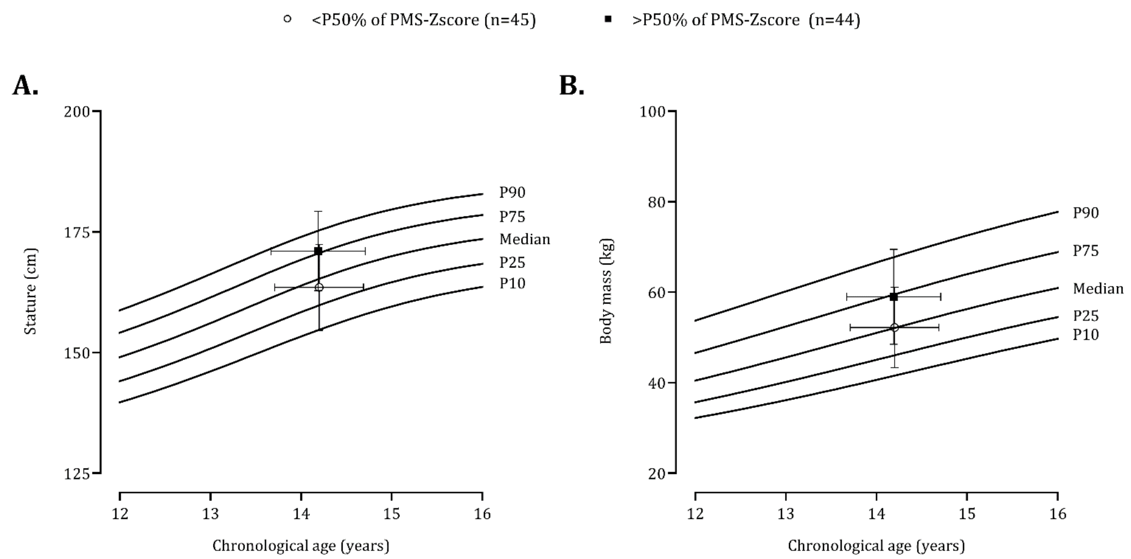

Figure 14. Growth charts mean by PMS z-score stature for chronological age and mean by PMS z-score body mass for chronological age.

In the mean analysis and the stature graph, the group below 50% z-scores PMS is between the 25th percentile and the mean, while the group above 50% is between the 75th and 90th percentile. The two groups are between the mean and the 75th percentile in the body mass graph.

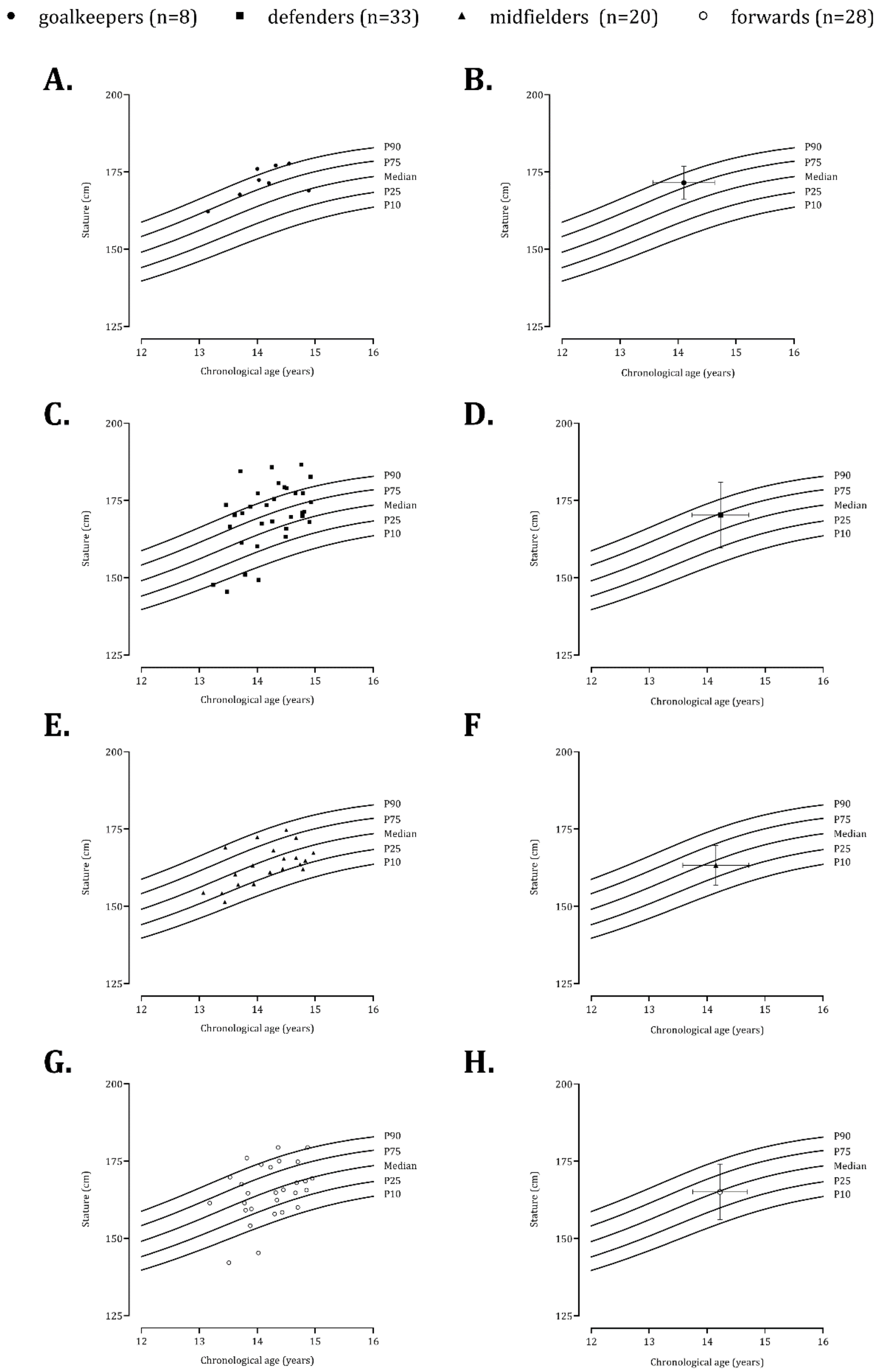

Figure 16. Growth charts individual by position stature for chronological age and mean by position stature for chronological age.

Regarding the position analysis, in the individual stature per chronological age (Figure 14), the goalkeepers are between the median and the 90th percentile. In the analysis by mean, they are between the 75th and the 90th percentile. In defenders, the variation occurs between below the 10th percentile and above the 90th percentile, and about the median value, it is between median and 75th percentile. In midfielders, the variation occurs between the 10th and the 90th percentile, and concerning the median value is between the 25th percentile. Finally, in forwards, there is a variation below the 10th percentile to above the 90th percentile to the median value; it is between the 25th percentile and the median.

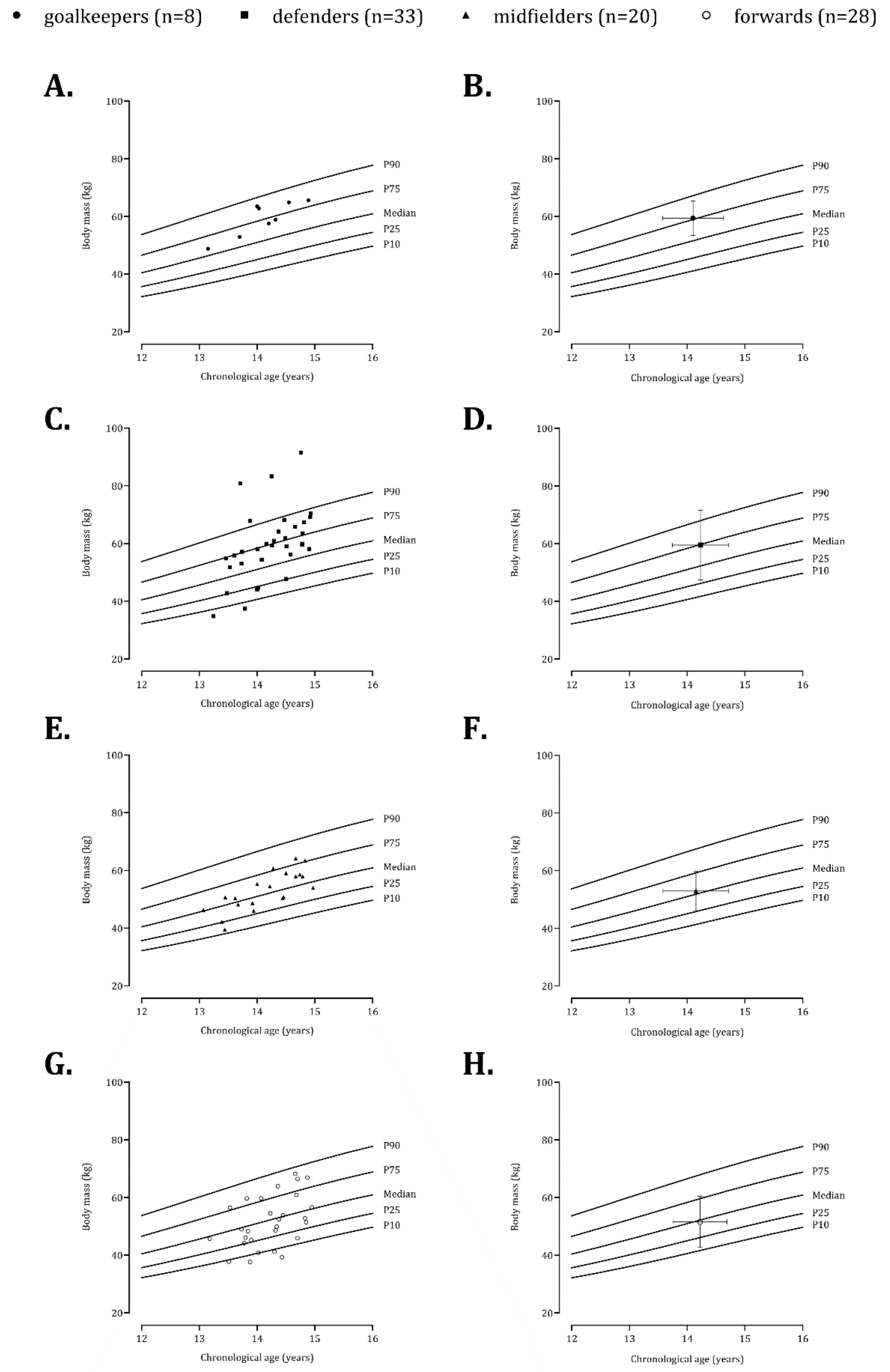

Figure 17. Growth charts individual by position body mass for chronological age and mean by position body mass for chronological age.

Regarding the analysis by positions, in the individual body mass per chronological age (Figure 15), the goalkeepers are between the median and the 90th percentile, while in the analysis by mean, they are between the 75th and the 90th percentile. In defenders, the variation occurs between below the 10th percentile and above the 90th percentile, and in relation to the median value, it is between median and 75th percentile. In midfielders, the variation occurs between the 10th and the 90th percentile, and in relation with value, it is between the median and 75th percentile. In forward, finally, in there is a variation below the 10th percentile to the 90th percentile, and concerning the median value, it is between the 25th percentile and the median.

From here onwards, all histograms will be displayed (from figure 16 to figure 27), relating to the various variables analyzed throughout the study by respective position: goalkeepers, defenders, midfielders and forwards.

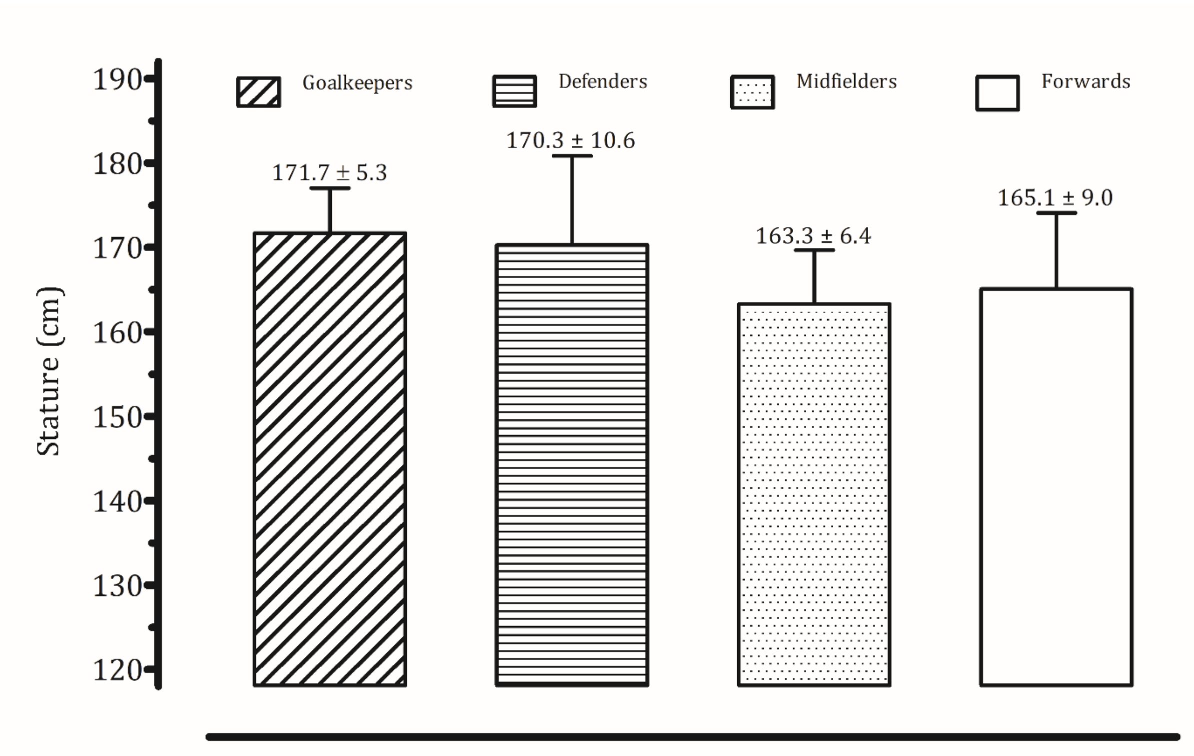

Figure 18. Stature by playing position.

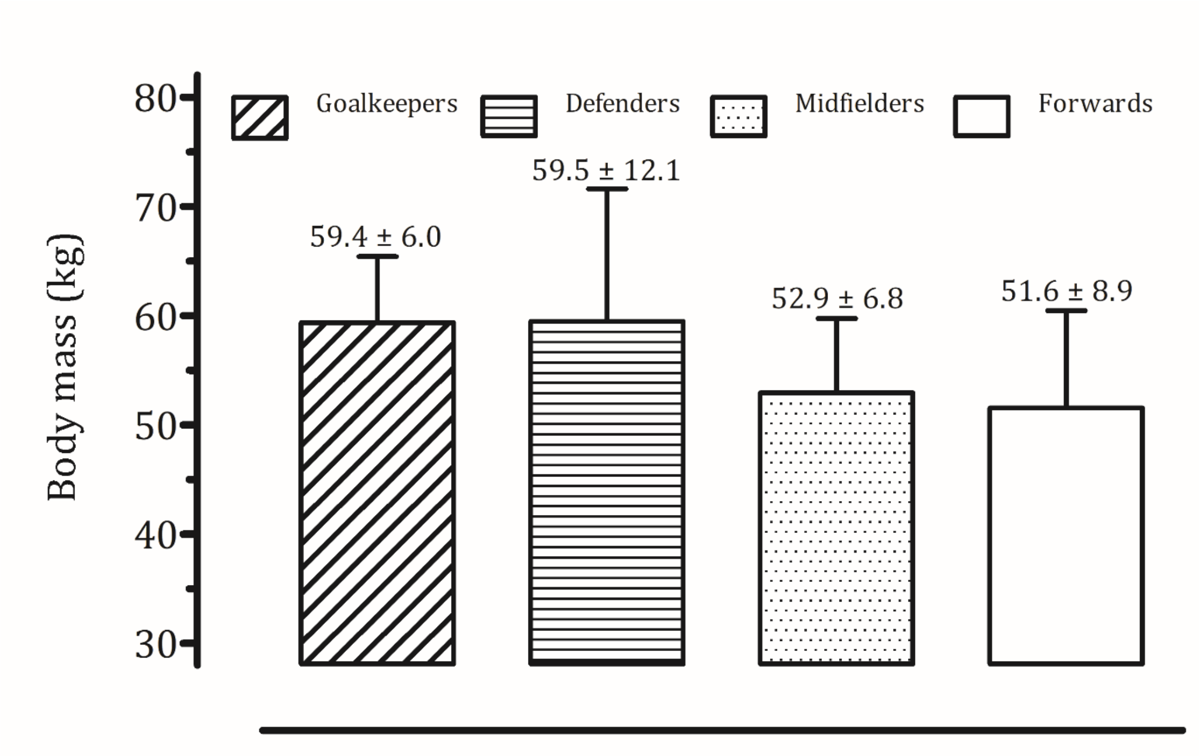

Figure 21. Body mass by playing position.

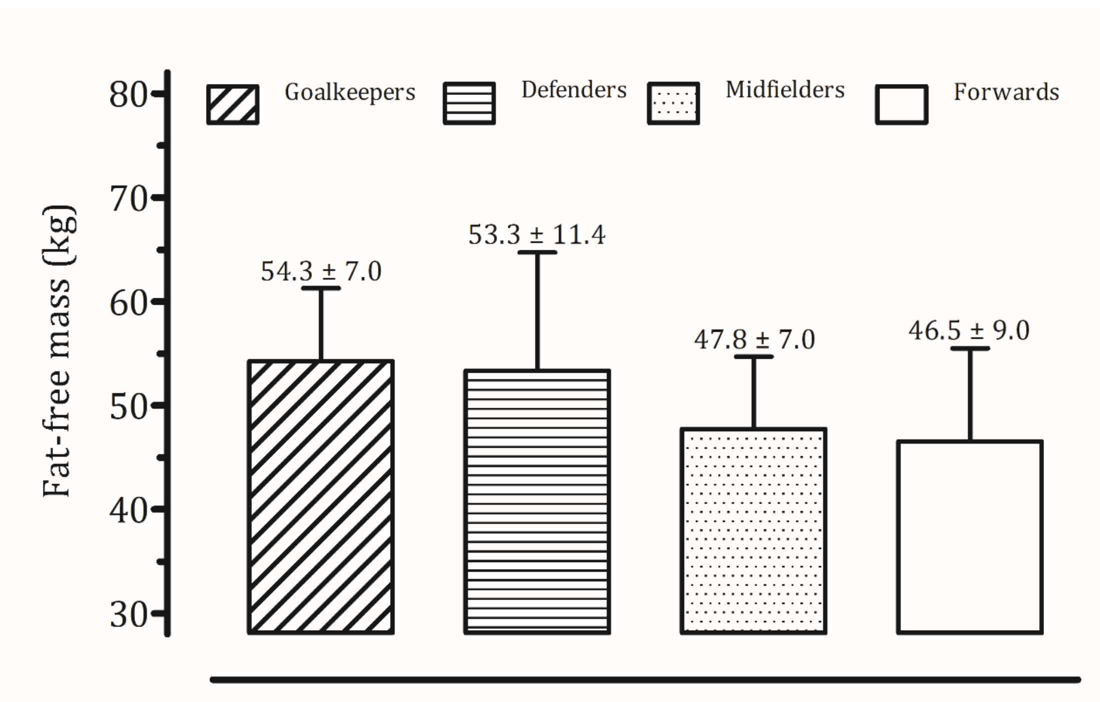

Figure 22. Fat-free mass by playing position.

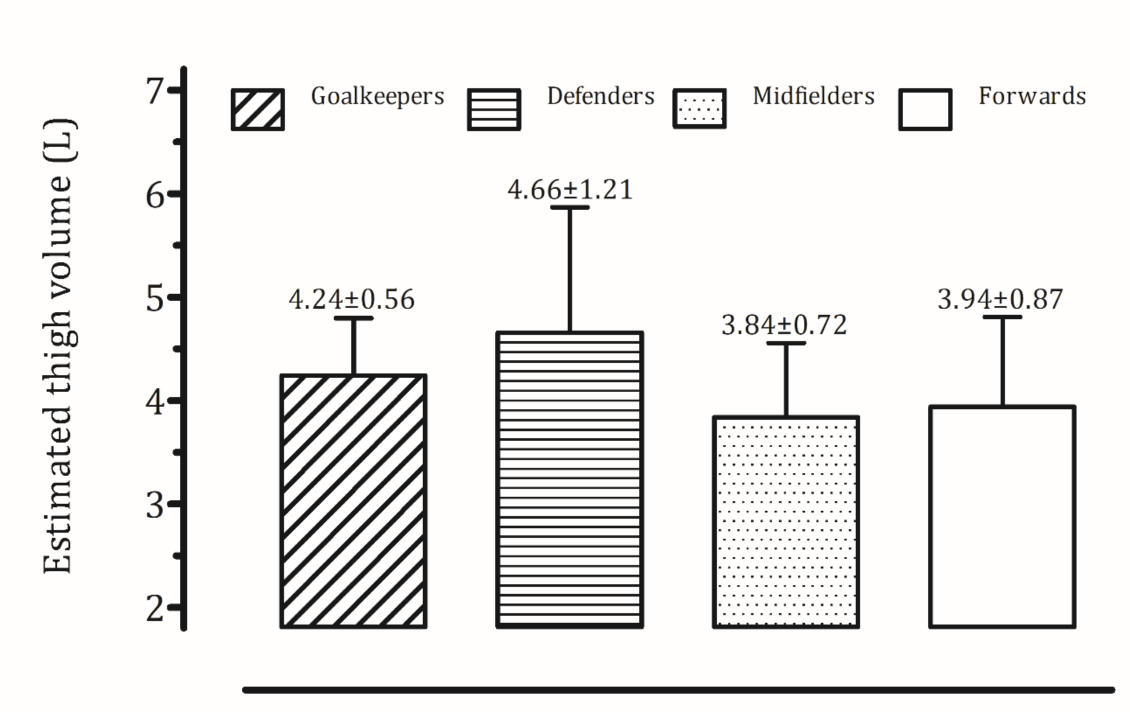

Figure 23. Estimated thigh volume by playing position.

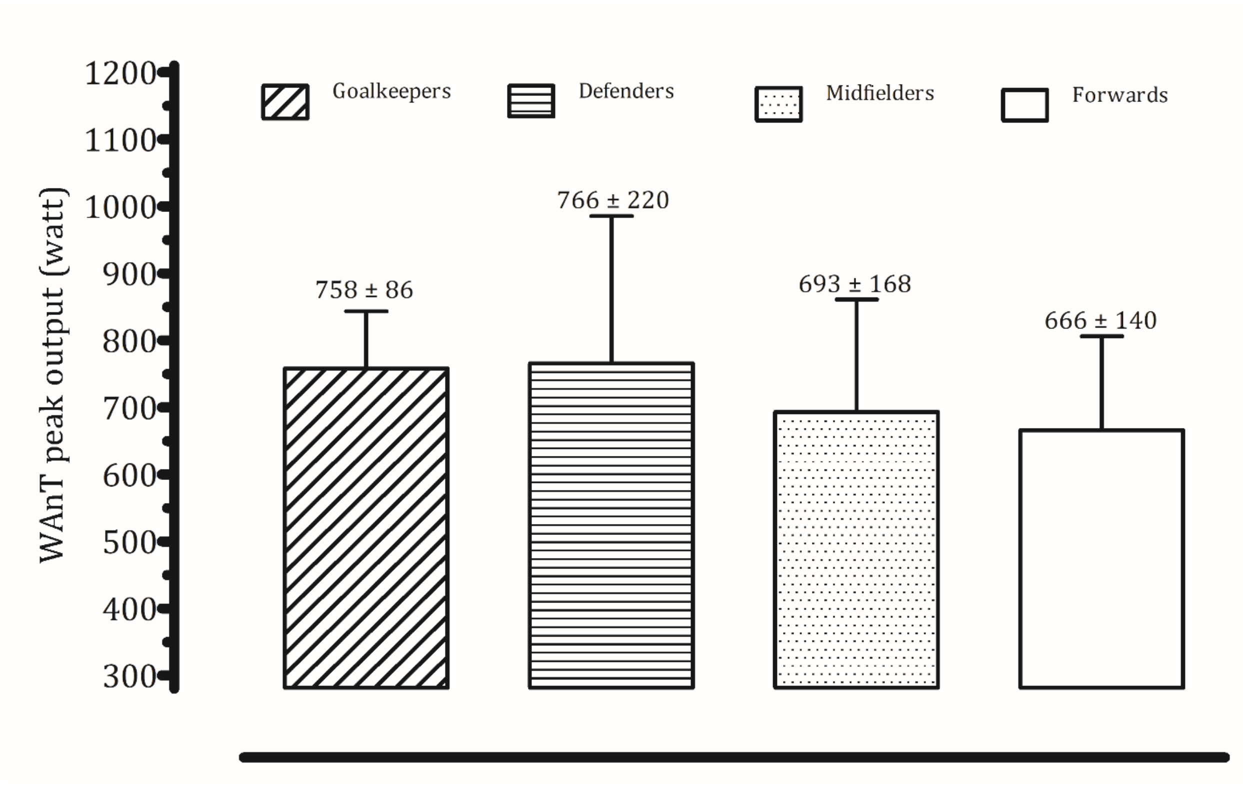

Figure 25. WAnT peak output (watt) by playing position.

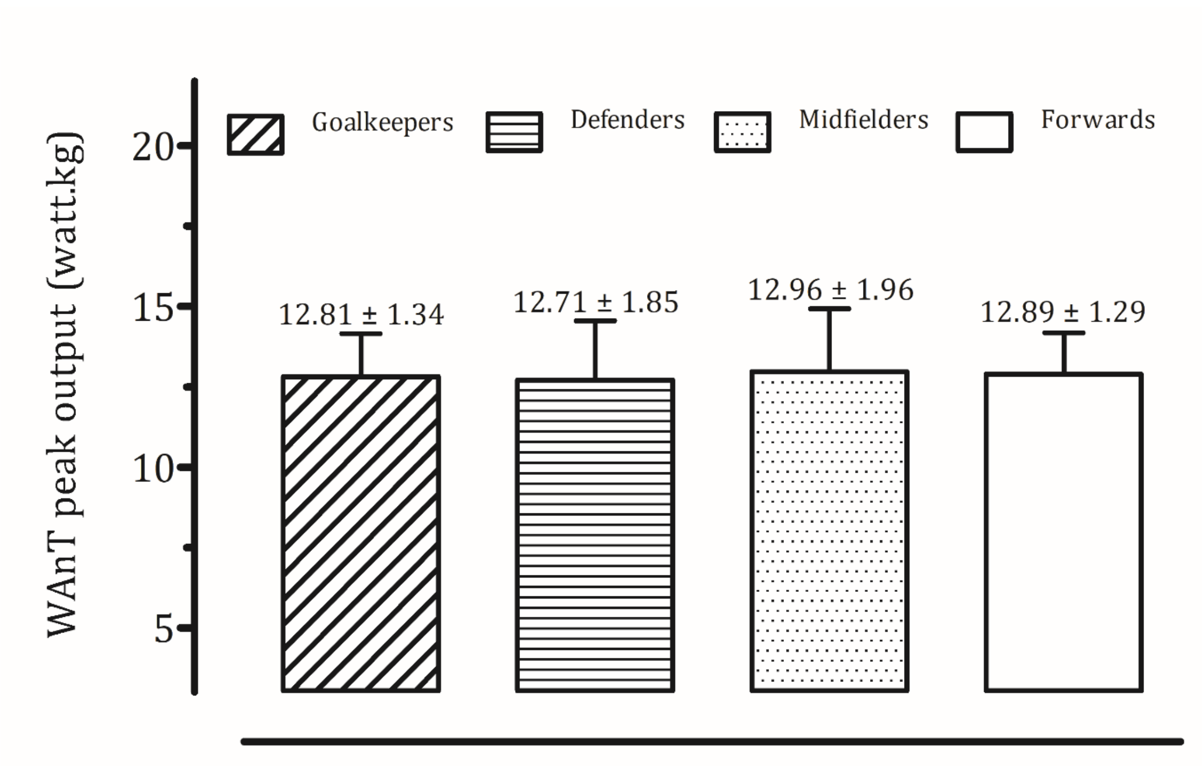

Figure 24. WAnT peak output (watt.kg) by playing position.

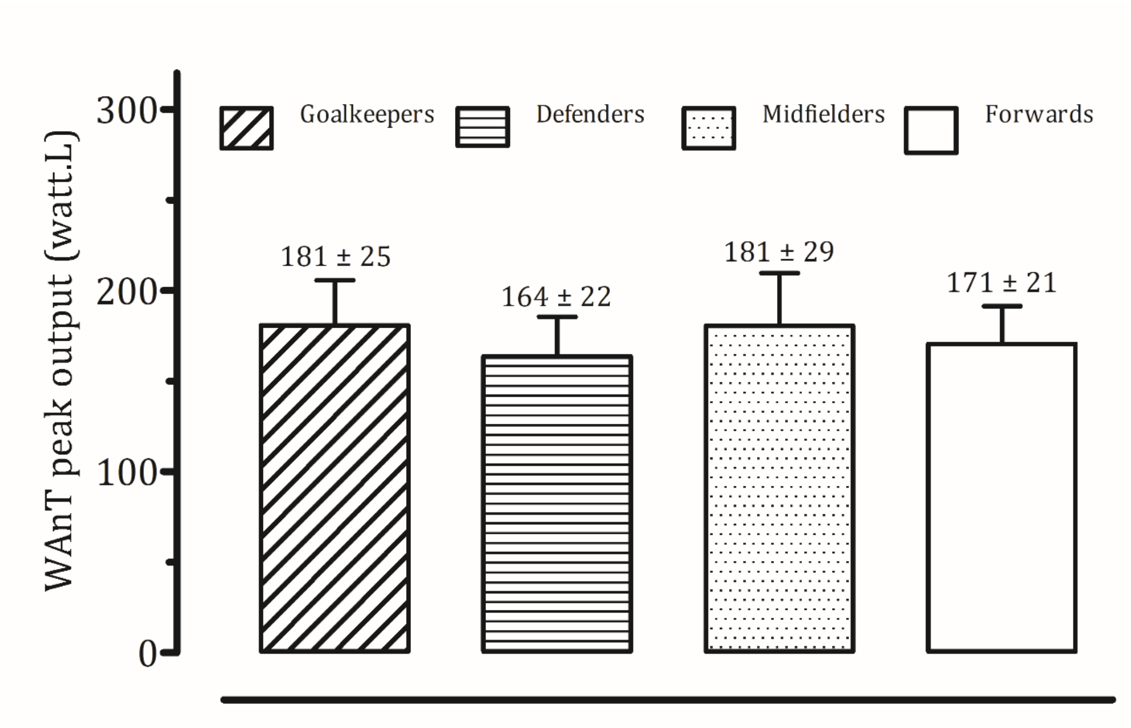

Figure 27. WAnT peak output (watt. L) by playing position.

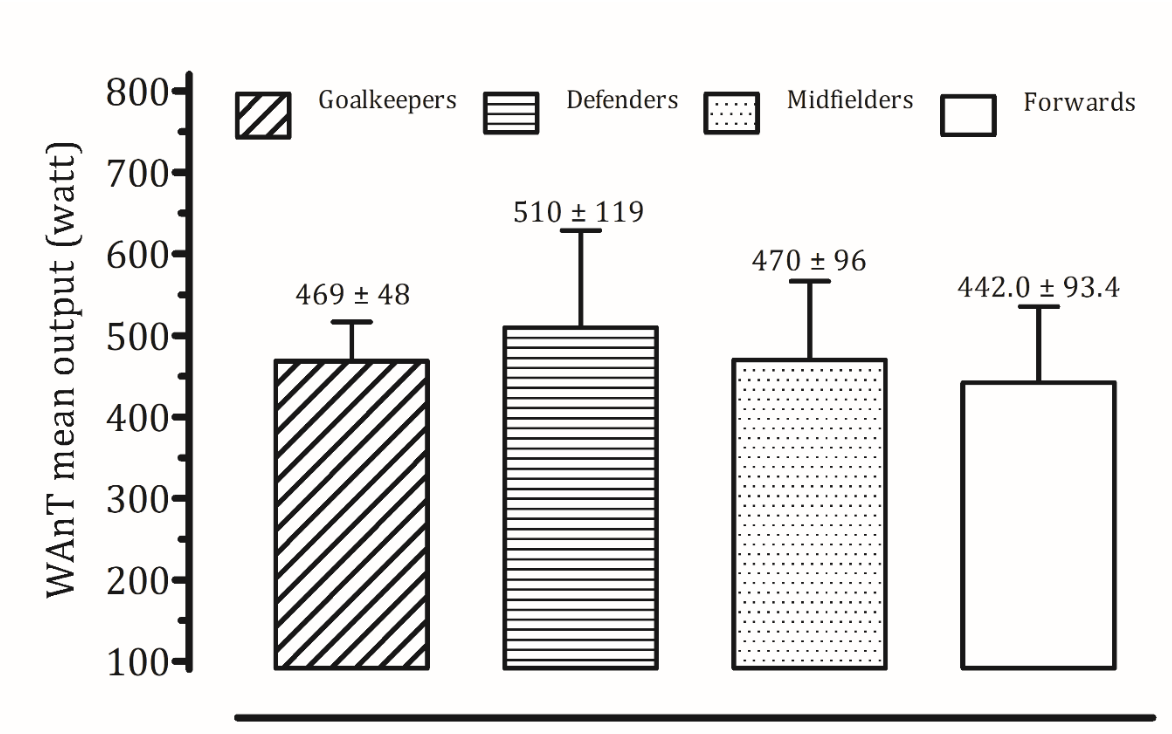

Figure 26. WAnT mean output (watt) by playing position.

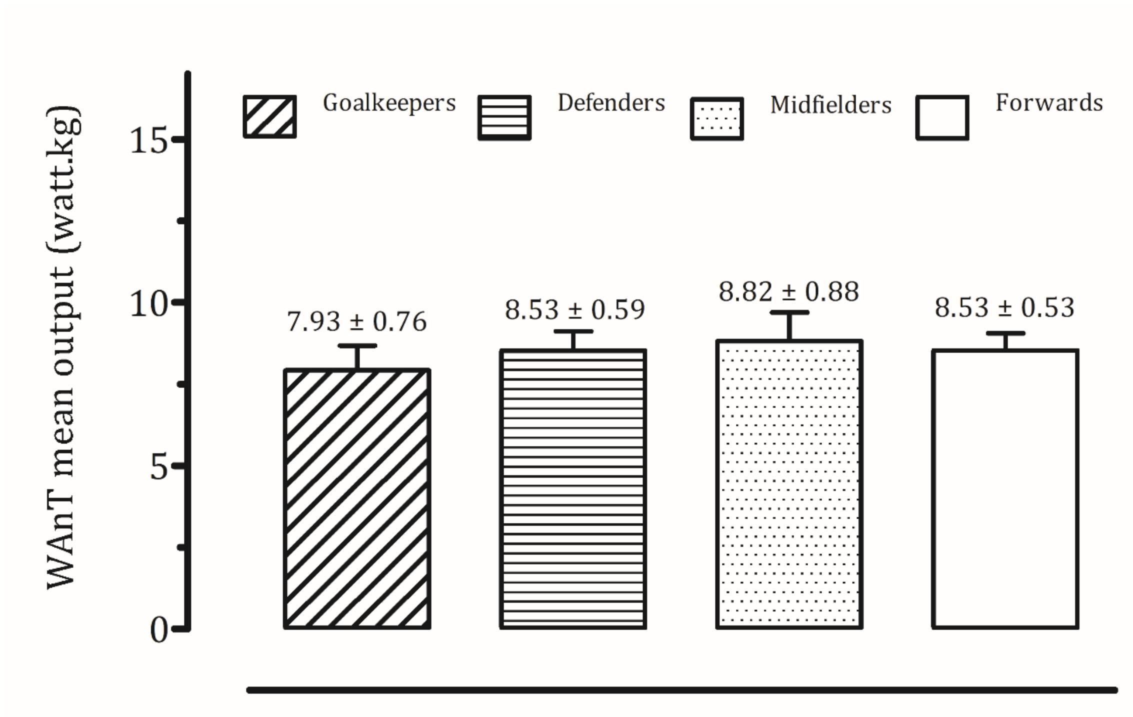

Figure 29. WAnT mean output (watt.kg) by playing position.

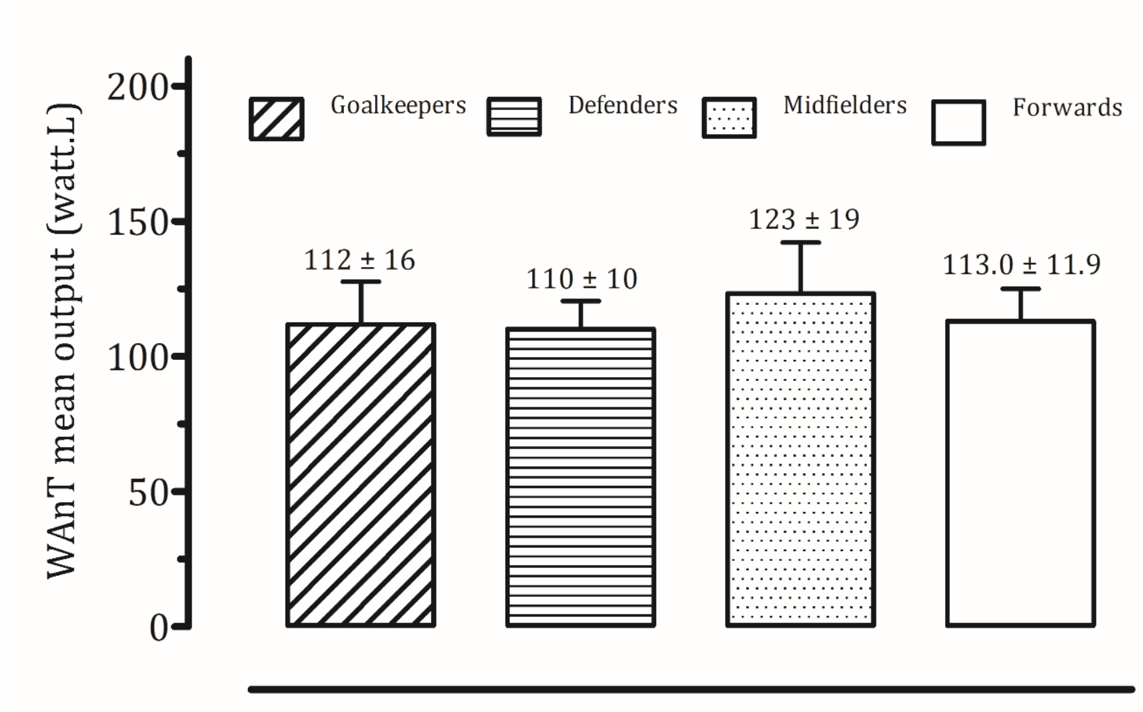

Figure 28. WAnT mean output (watt. L) by playing position.

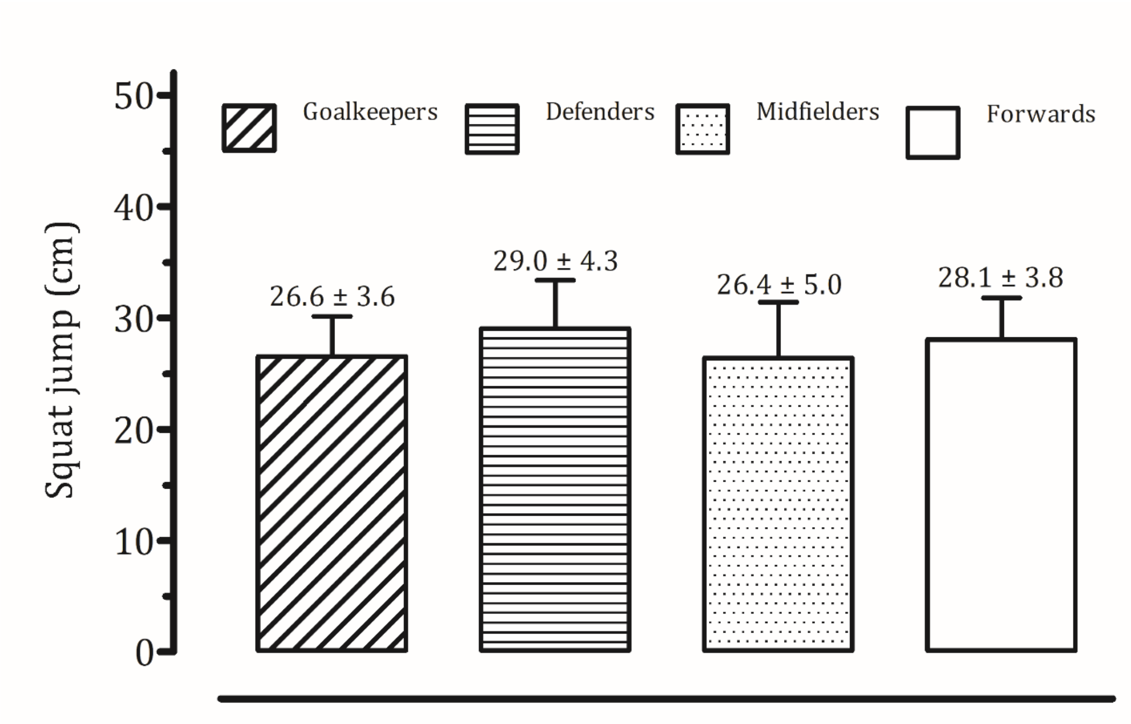

Figure 31. Squat jump by playing position.

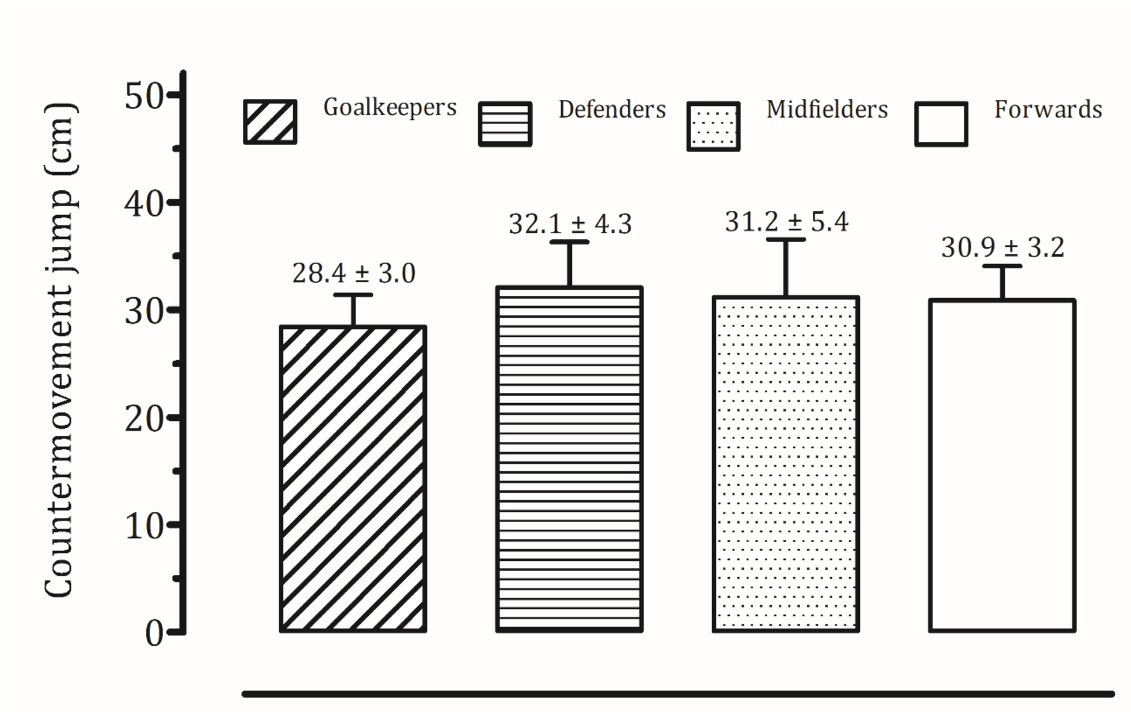

Figure 30. Countermovement jump by playing position.

CHAPTER III - DISCUSSION

Following chapter aims is to discuss the present findings in original aims and objectives of this research programme. A synthesis of findings will be presented in relation to current literature and how these findings have contributed to the existing body of knowledge. Practical recommendations to optimize the prescription of anaerobic fitness in youth soccer players will be discussed, based on the major findings from this thesis. The limitations of the present programme of research will be acknowledged before making recommendations for future research based on the current thesis and the evolution of soccer training methods, statistical analysis and technologies in recent years.

Main Findings

This dissertation was aimed to examine the contribution of body size, descriptors of body composition and biological maturation to inter-individual variability on anaerobic power outputs and two indicators of jumping performance among male adolescent soccer players aged 13.07-14.97 years. Chronological age emerged as correlated with body size given by stature, body mass and fat-free mass in addition to WAnT outputs (peak and mean) when expressed in absolute values, that is, watt. In parallel, attained %PMS corresponding to an indicator of timing presenter larger correlation coefficients than chronological age (R. Malina, 2014). In general, older players and the ones who already attained higher % of PMS at the time of measurements were more likely to be taller, heavier, particularly in fat-free mass component and perform better scores in WAnT test. The magnitude of explained variance for jumping performance was more modest compared to the test in the cycle-ergometer. Taking the preceding into account, biological maturation seemed to affect body size and this fact would recommend particular attention in the interpretation of functional tests requiring displacement of the body. Consequently, WAnT outputs should be interpreted in watt per unit of body mass and also in watt per liter of estimated thigh volume.

The Guidance Study sample was selected for several reasons: first, Fels reference values for percentage mature height were reported only for yearly intervals with a narrow band of variation because subjects were measured within 1 month of their birthdays; second, mean heights of boys 9 to 14 years in the Fels and Berkeley samples were similar to each other and to current United States reference values; third, means and standard deviations for percentage mature height at half-year intervals were reported for the Guidance Study; fourth, the Khamis-Roche method used the same half-year age intervals; fifth, mean percentage of mature height at each age from 9 to 14 years was similar in the 2 longitudinal samples.

The young soccer player

Young people produce less fatigue in high-intensity sessions, have a greater capacity to reduce fatigue due to the formation of substrates of the anaerobic metabolism and greater capacity of the oxidative system to restore anaerobic substrates (Ratel et al., 2006), as they manage to maintain high levels of peak power output only with rest periods of 30 seconds, while adolescents and men already need 5 minutes to do the same (Ratel et al., 2002). Throughout adolescence, concepts such as growth, maturation and development are defined to verify intra- and inter-individual variability, and certain changes that occur in the human body, such as increased muscle mass, increased glycolytic activity and improved muscle coordination allow differentiation between pairs. Topics such as sexual dimorphism, and the differences between children and adults were accentuated with the evolution of evidence on the theme of anaerobic metabolism, and the values of peak power output and mean power output when compared, occurring a normalization in relation to body size, young people have lower values than adults (Armstrong, 2007). When a comparison between child-adult is performed, it appears that the decline of this substrate is much smaller in children compared to adults (Kappenstein et al., 2013). However, there are already studies showing an increase in glycolytic enzymes in adults compared to children (Berg et al., 1986; Haralambie, 1982), and these changes make there is a greater dependence on anaerobic glycolysis in high-intensity sessions, leading to a higher peak lactatemia in adults (15.8 mmol/L) compared to children (8.5 mmol/L) (Ratel; et al., 2002). These questions have a relevance for differentiating rest period protocols between a senior vs. Training for children and youth, as children need less time to restore depleted phosphocreatine stores (D. J. Taylor et al., 1997).

Maximal short-term intensity efforts in young people

Short-term maximal efforts are considered predictors of success in team sports, especially soccer. The distinction currently existing in human bioenergetics allows us to differentiate the glycolytic from the oxidative system, and to understand the fact that children, when performing physical exercise, are mostly in anaerobic conditions (Armstrong, 2007; Rumpf et al., 2011). In many of the studies carried out, two concepts for measuring anaerobic power are presented, such as the peak power output and the mean power output, which consists of maintaining power values in tests performed with a duration ranging between 6 and 30 seconds (Neil Armstrong & McManus, 2011; Barker & Armstrong, 2011). Due to all these previously mentioned characteristics of the metabolism of young athletes, they are able to produce higher levels of energy in maximal and intermittent efforts, through the phosphagen pathway and consequently through its energetic substrate, adenosine triphosphate/phosphocreatine (ATP/PC), however little is known whether somatic maturation will lead to an increase in intramuscular ATP/PC levels in young people (Armstrong et al., 2015). The interaction between the oxidative system and the glycolytic system was noticeable, and a clarification of concepts is needed between maximum intensity exercises and maximum exercises, as maximum intensity exercises produce two to four times mechanical power higher.

(i) Maximum intensity exercise: performance of full intensity exercises, where the predominant, but not exclusive, energy source comes from anaerobic metabolism;

(ii) Anaerobic Fitness: ability to perform maximum intensity exercises. It is the competency to generate power in a few seconds (5 seconds) and maintain high power values for a short period of time (60 seconds).

Physiology of soccer and match performance

The study inherent to the physiology of soccer starts today, to be differentiated, with the perception that its performance comes from a multidimensional context (Dolci et al., 2020; Stølen et al., 2005), and each time moreover, a distinction is made between senior soccer and youth soccer (Palucci Vieira et al., 2019), showing that training must be appropriate to both chronological and biological age (Lloyd et al., 2014; Palucci Vieira et al., 2019). Studies of physiology in soccer, carried out in young people, show that game performance increases with chronological age (Buchheit, Mendez-Villanueva, et al., 2010), and young soccer players usually cover 5 to 8 km per game, which comparatively for adults, the distance covered is shorter (Capranica et al., 2001; Carling et al., 2009; Castagna et al., 2010; Goto et al., 2015; Mohr et al., 2005; Rebelo et al., 2014; Reilly, Williams, et al., 2000). However, there is clearly a lack of evidence on topics such as acute and residual fatigue in young soccer players (Palucci Vieira et al., 2019).

Playing position and sport specialization

As in senior soccer (P. S. Bradley et al., 2010; E Rampinini et al., 2007; Ermanno Rampinini et al., 2009), position also impacts the demands of the game (Aslan et al., 2012; Buchheit, Mendez-Villanueva, et al., 2010), and hence, the central midfield covers greater distances compared to defenses and forwards (Castagna et al., 2010). The central defender performs shorter distances and perform activities with less intensity compared to full-backs/wing midfielders and forwards (Buchheit, Mendez-Villanueva, et al., 2010). In much of the training of young soccer players, differences are accentuated with age, both in the volume and intensity of the training load (Wrigley et al., 2012), assuming that there must be a link between the education system and the sports system (Scantlebury, Till, Sawczuk, Dalton-Barron, et al., 2020; Scantlebury, Till, Sawczuk, Phibbs, et al., 2020).

However, early choice of position leads to a loss of physical and tactical skills (Malina et al., 2000), and motor performance must be adapted to age, biological maturation, and training considerations (Abarghoueinejad et al., 2021). Although there is some supporting evidence, there is some controversial research (Mendez-Villanueva et al., 2013) which suggests that when considering speed thresholds, young soccer players tend to perform more sprints (Buchheit, Mendez-villanueva, et al., 2010) and running the same total distance as adults (Harley et al., 2010). Some age-related differences are reported, such as running performance in both parts (Castagna et al., 2010) and with young soccer players being able to maintain high-intensity running in the second part better than adults (Castagna et al., 2003, 2010).

Biological maturation as a confounding factor for talent identification

The respective interactions between youth metabolism and growth and maturation become essential for anyone working in youth soccer (Lloyd & Oliver, 2019). Coaches must be aware of the education of the young athlete's body, and that there are training stimuli suitable for different types of maturation status, such as pre-pubertal, circa-pubertal and post-pubertal). When conducting training aimed at young athletes, their proper control and monitoring becomes an essential piece (Baxter-Jones et al., 2005; R. M. Malina et al., 2015), also for a differentiation of protocols according to biological age (Chris Towlson et al., 2020). With the variability of biological maturation (R. M. Malina et al., 2015), the peak height velocity occurs at 12 years old in girls with respective variability between 10 and 15 years old, and in boys it occurs at 14 years old with variability between 11 and 16 years old (Armstrong, 2007; R. M. Malina, Bouchard, et al., 2004).

Maturation protocols have emerged over the years, such as predicted adult height (Khamis & Roche, 1994), age at peak height velocity and maturity offset (Mirwald et al., 2002), however, in the latter, several have been observed. limitations (Kozieł & Malina, 2018; R. M. Malina et al., 2016; R. M. Malina & Kozieł, 2014a, 2014b). These indicators of biological maturation have led to new proposals adapted to an athletic population (Fransen et al., 2018) and others are considered as an alternative to original equations (Moore et al., 2015). However, more recent equations suffer from the same limitations as the original ones (Kozieł & Malina, 2018; Nevill & Burton, 2017).

Some of the functional capacities can be altered either pre or post peak height velocity, and thus produce training gains and adapt protocols for young people with different maturity statures (Armstrong & Barker, 2011; Baquet et al., 2003; Harrison et al., 2015; Melitta, 2014), producing higher levels of metabolic power but with greater fatigue and longer recovery time. Even though the short-term power output is predominantly anaerobic, its aerobic contribution ranging from 10 to 44% is greater in children compared to adults due to faster pVo2 kinetics (Armstrong et al., 2015).

Testing procedures for talent identification

With the assessment of anaerobic fitness (Neil Armstrong & Welsman, 2020), the WanT test is considered the gold-standard method (Bar-Or, 1987; Driss & Vandewalle, 2013). In carrying out the test, and its relationship with glycolytic metabolism, it shows that the rate of ATP utilization is a performance limiting factor in Wingate (Beneke et al., 2002), with limitations of glycolysis, PCR breakdown and re-phosphorylation oxidative (Beneke et al., 2007).

When this test is performed in young athletes, the presentation of peak power and mean power output values relatively (W/kg) causes problems (Nevill et al., 1992; Nevill & Holder, 1995; Tanner, 1949), and data modulation is presented as a solution using allometric scaling techniques, such as "Size-free expression" (Armstrong, 2007). However, the WanT test is a laboratory test, and ergometers are currently appearing on a large scale in soccer clubs and gyms, and as such, it would be interesting to measure the levels of agreement between the different instruments (Bland & Altman, 1995; W G Hopkins et al., 2001), to verify if these ergometers are instruments with sufficient validity and reliability for the prescription of anaerobic training in young athletes, assuming a scientific concept, the ecological validity.

The Wingate Anaerobic Test (WanT) has been, over time, an important laboratory test of high intensity and short duration performance in pediatric exercise physiology, and with special attention in soccer (Al-Hazzaa et al., 2001; Meckel et al., 2009). Several associations have been made to terrain tests such as the

RAST test (Meckel et al., 2009), where significant correlations were found between the fastest sprint (r=0.62) and the total sprint time (r=0.71) and association with the Field anaerobic shuttle test (FAST) and with the Cunningham and Faulkner treadmill anaerobic speed test (AST).

All values that come from the WanT test are mainly influenced by chronological age, both in peak power output and in mean power output, where with the evolution of the literature it became possible to determine normative data (P. T. Nikolaidis et al., 2018). However, several years ago, there was an attempt to emerge a treadmill test, which also demonstrated significant correlations with WAnT (peak power, r = 0.82; mean power, r = 0.88) in young athletes, however the literature is still is sparse for this test (Oliver et al., 2007).

New paths are being sought for a true interpretation of the short-term power output of young soccer players, and meeting this statement, advanced statistical techniques must be performed both in cross-sectional and longitudinal studies. Multiplicative multilevel modeling has gained enormous preponderance in the assessment of young athletes, which has already been addressed in two studies (Neil Armstrong et al., 2019) with the accentuation of sexual dimorphism in the assessment of anaerobic power (Neil Armstrong & Welsman, 2019).

It is intended to further clarify the prescription of anaerobic training through scientific studies, however there should be not only laboratory studies but also field studies, thus giving greater ecological validity to the same theme, or even understanding the anaerobic trainability in both genders (Voisin et al., 2019).

Limitations of the present study

Few studies (Armstrong et al., 2015; Glenmark et al., 1992; Haralambie, 1982; Jansson & Hedberg, 2007; Kaczor et al., 2005) carried out invasive technologies including muscle biopsies which are note recommended for young people. Non-invasive methods such as magnetic resonance spectroscopy appeared as valid alternatives in pediatric sport sciences (N Armstrong & Van Mechelen, 2017; Neil Armstrong & Fawkner, 2008; Barker & Armstrong, 2011). Unfortunately, the present study did not assess biological maturation using skeletal age and estimated thigh volume was derived from anthropometry.

The present study corresponds to a quasi-experimental design and obviously the results should be interpreted with caution, particularly regarding the nature of relationship between independent and dependent variables. This is a descriptive study which does not imply any causal effect between playing position and the morphological nor the functional characteristics. Meantime, the association between somatic maturity groups and Wingate outputs needs to be examined among non-athlete adolescents. In addition, although this sample included 89 male adolescent soccer players, it does not correspond to a Portuguese representative study of initiates.

Regarding the assessment of anaerobic fitness, this study adopted the Wingate test which provides maximum power in addition to average power and fatigue index (Neil Armstrong & Welsman, 2020). Although other testing protocols are often suggested as valid alternatives, such as the force-velocity test, the current results confirmed previous evidences about the interdependence association between biological maturation and maximal short-term performance in cycle-ergometer tests (Falk & Bar-Or, 1993). In that particular, maturation was directly associated to peak power and mean power values (Neil Armstrong et al., 1997). Nevertheless, previous research assessed young adult collegiate-level soccer players and evidenced a modest association between WanT and running anaerobic sprint test that is often termed as RAST (Keir et al., 2013). More recently (Bongers et al., 2015) the interrelationship among RAST and the laboratory-based test outputs (WAnT peak, WAnT mean) was examined and it was concluded that WAnT-mean presented a larger coefficient with RAST compared to WAnT-peak, respectively 0.91 and 0.86. Future studies may consider the analysis of force-velocity protocol among adolescent soccer players contrasting in biological maturity status, although the preceding test did not inform about the 30-s output that is believed to be relevant in intermittent team sports (Coelho-e-Silva et al., 2012).

The literature already showed that short-term power output was affected by intra-individual error of about 3% (Eric Doré et al., 2003). The present study did not inform in-field reliability due to time-constraints. Error may also occur among predictors used to explain inter-individual variance in the present study. Body size, growth status and maturation may be viewed independently but also as combined factors requiring analytical methods to avoid collinearity in the prediction of performance (Pearson et al., 2006).

Among young people, allometric coefficients should be used as an alternative to linear ratios (Armstrong, 2007; N Armstrong & Van Mechelen, 2017; Nevill, 1994; Nevill et al., 1992; Nevill & Holder, 1995; Tanner, 1949; Joanne R Welsman & Armstrong, 2000). The need to use allometry to normalize the body dimension in relation to the physiological variable is due to the high correlations between the relative value of the physiological variable (W kg-1) and the size descriptor (kg). Furthermore, assuming a relationship close to linearity, using regression techniques it would be expected that the intercept would occur close to the origin, which is rarely the case (Nevill & Holder, 1995). Besides the previously mentioned limitation, the literature (P. Nikolaidis, 2011) often adopts watt per unit of whole-body mass, although the test is performed in a sitting position. Regardless of adopting linear ratio or an allometric approach, researchers and practitioners need to express WAnT outputs as watt per liter of lower limb volume or simply watt per liter of thigh volume.

When groups characterized by different morphological size and composition are compared, as in the present study that performed multiple comparisons by playing position (goalkeepers versus outfield players; defenders versus midfielders; defender versus forwards; midfielders versus forwards), it is strongly recommended the adoption of an allometric approach (Nevill, 1994). A previous study (Rebelo-Gonçalves et al., 2015) assessed 145 soccer players to examine variation of performance variables by position from under-13 (infantiles) to under-18 (juveniles). Note, however, that according to the assumptions of ontogenetic allometry, scaled coefficients may be different for pre-pubertals, circumpubertals and post-pubertals. By inference, each age-group needs to confirm the best solution to obtain a dimensionless exponent (linearity, 2/3 or 3/4 laws). In addition, the best size descriptor to interpret physiological variables may change across years of maximum growth as illustrated for maximal oxygen uptake among adolescent soccer players (Valente-Dos-Santos et al., 2015).

SYNTHESIS OF FINDINGS

The inclusion of bio-banding strategies is believed to facilitate the holistic development of youth soccer players particularly the ones who are classified as late maturing by leading to tasks adjusted to their performance and skills levels (B. Bradley et al., 2019). Recent studies have grouped young athletes by categories based on mass, height or maturation (Cumming et al., 2017, 2018).

In a study of 66 young soccer players aged 11-14, from four premier league soccer academies (Southampton, Stoke city, Reading and Norwich), with the methodology for measuring adult height prediction using the Khamis-Roche method, and with an "early maturers" and "late maturers" rating of 8 players each via z-score based on % predicted adult height and the age and gender reference values from the Berkeley Guidance study. There were 3 games 11 vs. 11 with 25 minutes each part, where athletes were grouped based on attributes associated with growth and maturation rather than chronological age, and to report young people's perceptions, unnamed audio interviews were carried out with a duration of 12-17 minutes, and young soccer plyers called "early maturers" expressed that the game becomes more physically challenging, has a greater adaptation of pacing and greater emphasis on technique and tactics, while, for "late maturers" the game becomes less challenging physically, greater opportunity to develop the technique, the physical and its physiological components (Cumming et al., 2018). Meantime (B. Bradley et al., 2019) with basically the same study design procedures, but with a sample of 115 young soccer players from three English academies (Bournemouth, Watford and Exeter city) shows that this bio-banding approach promotes the holistic development of both early and late maturing young soccer players. In the same year, but with a sample of 25 young soccer players (Abbott et al., 2019) and with the same procedures as the two previously reported studies, however, their analysis was not only based on a qualitative perspective, but also added a quantitative perspective. With the advancement of the literature on this topic, safety and positive or negative effects have been evaluated (Hill et al., 2020; Rogol et al., 2018) and several methodologies have been performed in bio-banding studies not converging with the initial studies by Professor Sean Cumming (Lüdin et al., 2021; Romann et al., 2020; Christopher Towlson et al., 2021).

Briefly, bio-banding have several functions. Firstly, competition organized by weight categories (which already happens in combat sports), maturational bands, chronological age, but also according to strength and fitness level by organizing band-specific programs that consists to adequate stimulus on injury prevention and opportunities to play and compete. Additionally, for the purpose of talent identification, the results derived from young athletes would be interpreted according to their biological characteristics instead of doing it by chronological age (Cumming et al., 2017, 2018; Rogol et al., 2018).

In a 7-year longitudinal study of 267 soccer players aged 12-19 years, measured over 7 years, with a multilevel modeling approach, where dribbling and sprint ability were measured, the data appear to increase with age in these 2 characteristics between at 12 and 14 years old, however, the young athlete differs in timings and times, and then between 14 and 16 years old there is a greater increase in sprint, and only from 16 years old is there a rapid development of dribbling, having this as discriminating factors that describe size, such as lean body mass, or age, or even environmental factors such as hours of practice practice and game position (Barbara C H Huijgen et al., 2010). In another 5-year longitudinal study with 130 young soccer players aged 14-18 years old, where there was a differentiation between players who made it to professionals (n=53) and those who did not make it (n=77), with the help of a longitudinal mixed linear model, soccer endurance was predicted with a two-level hierarchical model, showing that from 15 years onwards, near to peak height velocity in young male soccer players, athletes who reached a professional level have a faster development compared to their non-professional peers, largely due to additional and specific football training (Roescher et al., 2010). Meantime, a new study appears that corroborates the previous evidence, with 492 young soccer players, ranging from under-13 to under-19, evaluated in the Interval Shuttle Run Test (ISRT) in approximately 950 measurements, between the 2000/01 and 2009/2010 seasons, where there is an approximate 50% improvement in the ISRT in different age groups, that is, this information has implications at the level of identification, selection and subsequent orientation of children's talent in soccer. Several characteristics underlying performance evolve with chronological age, one of which is the capacity for interval endurance in young footballers (Elferink-Gemser et al., 2012). Interval endurance capacity assessed in 113 young soccer players proves to be a crucial feature in the development of young soccer players with young players aged 12-15 years having worse performances compared to players aged 16-18 (Visscher et al., 2006). However, when we address the issue of identifying talent in soccer, not only the physiological perspective should be questioned, but also its technical perspective, and currently, in an ideology of creating talent identification programs, we talk about a multidimensional perspective (Burgess & Naughton, 2010; Barbara C H Huijgen et al., 2014; Vaeyens et al., 2006). This issue is verified in a study of 270 soccer players aged 10-18, with more than 660 measurements in the Loughborough soccer passing test (LSPT) and a multilevel modeling approach, which subdivided selected young soccer players (n=269) and de-selected (n=50) and it was found that there were greater improvements, about 32% in the combination between speed and accuracy and the selected soccer players had better values in this aspect, showing that there must be a diversification of practice in soccer training combining the speed and precision for further development of young soccer players (B C H Huijgen et al., 2013).

Training prescription according to maturity levels meets the specific readiness of the young soccer player (Abbott et al., 2019; Gabbett, 2022; Jayanthi et al., 2021, 2022; McBurnie et al., 2021; Murray, 2017). By using the percentage of predicted adult stature, considered as an indicator of somatic maturation, it has been suggested that the interval 85-90% overlaps to circumpubertal period, corresponding to a decisive phase in the transition from childhood to adolescence (Cumming et al., 2017). Bio-banding was segmented into the following stages (R. M. Malina et al., 2019): (I) At-TO (≥ 78.0% and < 85.0%); (II) TO-to-PHV (≥ 85% and < 90.0%); (III) At-PHV (≥ 90.0% and < 93.0%); (IV) Post-PHV (≥93.0%). Also very important, bio-banding adjusts technical and tactical requirements (Romann et al.,

2020) and, consequently, increases the pedagogical efficiency (Hill et al., 2020). Biological maturation is known to be associated to absolute peak oxygen uptake and capacity to produce energy using anaerobic systems. The preceding physiological parameters showed greater improvement nearby age at peak height velocity (R. M. Malina, Eisenmann, et al., 2004; Philippaerts et al., 2006).

The period of peak height velocity (PHV) has gained its importance in soccer (R. M. Malina et al., 2021) not only for a matter of the development of the training of physical qualities (R. M. Malina, Eisenmann, et al., 2004), as well as the variation of sport-specific skills (R. M. Malina et al., 2005), but also from a pediatric injury prevention perspective (Faude et al., 2013; Le Gall et al., 2007; Murray, 2017; Chris Towlson et al., 2020; van der Sluis et al., 2014, 2015). A longitudinal study (Philippaerts et al., 2006) assessed 33 adolescent soccer players aged 10.4-13.7 years at baseline and demonstrated intra-individual peak changes in anaerobic capacity close to age at peak height velocity. This information is relevant for coaches for an individualization of training load, which is a central aspect in long-term-athletic development plans (West et al., 2020). Bio-banding may be adopted as a beneficial strategy for the development of anaerobic capacity and power in young athletes. It was demonstrated (Kemper et al., 2015) that young athletes having an increment equal to 0.6 cm or above, per month, in height in parallel to an increase equal to or above 0.3 kg/m^2 in body mass index where more likely to be injured. In summary, decisions to implement training optimization combined with reduced risk injury should be viewed as essential in youth sports. Quality enhancement of youth sport programs is being implement by the Portuguese Soccer Federations by classification the quality of the programs in a scale 1-5 which will have implications in economic values to be transferred from professional clubs to youth academies.

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