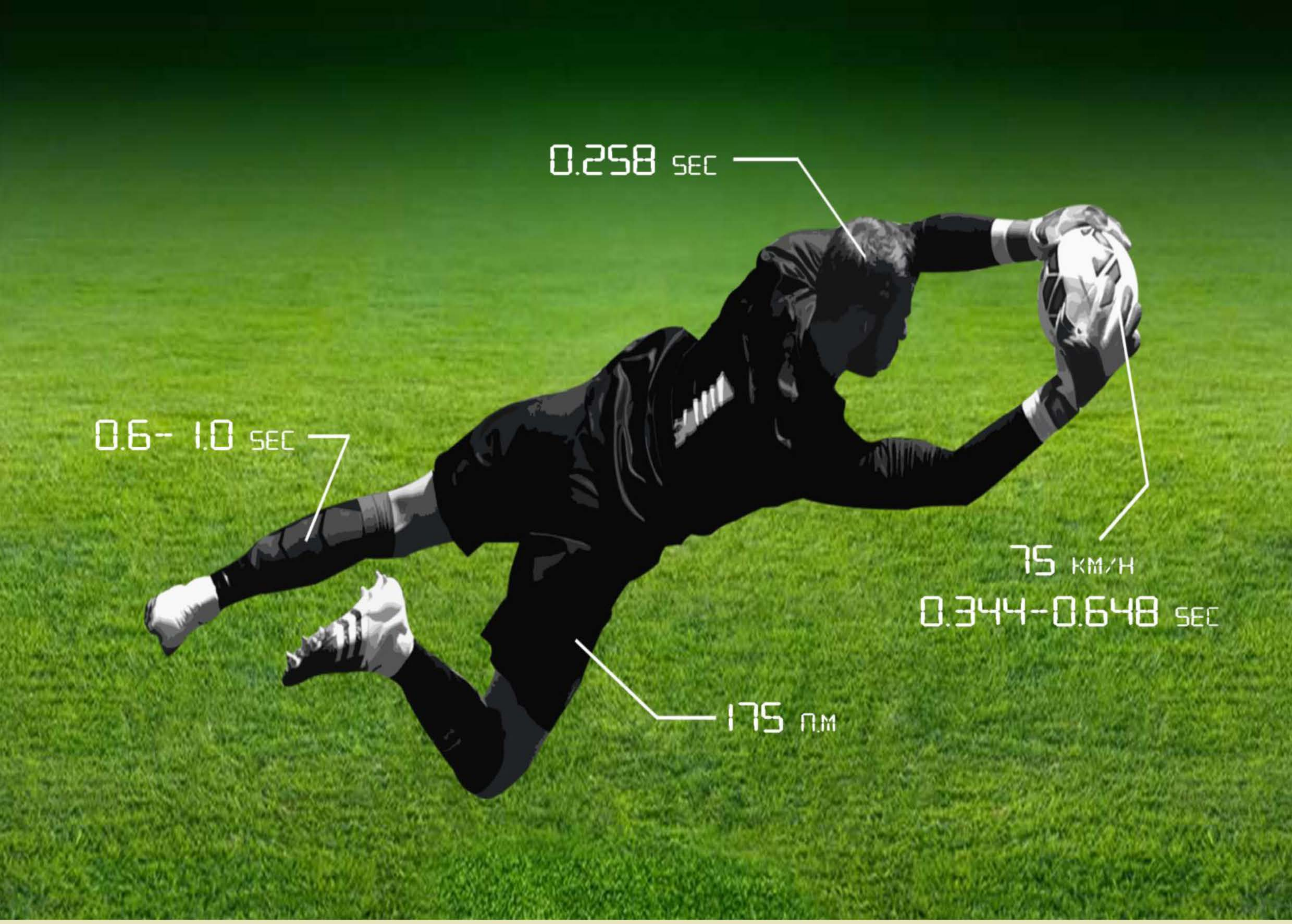

Ricardo Rebelo Gonçalves

MULTIDISCIPLINARY STUDY OF PERFORMANCE CHARACTERISTICS IN SOCCER GOALKEEPERS

Thesis for the degree of Doctor of Sports Sciences in the branch of Sports Training, supervised by Prof. Dr. António J. Figueiredo, Prof. Dr. Manuel J. Coelho-e-Silva and Prof. Dr. Antonio Tessitore and submitted to the Faculty of Sport Sciences and Physical Education of the University of Coimbra.

September 2015

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Universidade de Coimbra

UNIVERSITY OF COIMBRA
Faculty of Sport Sciences and Physical Education

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FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

POPH PROGRAMA OPERACIONAL POTENCIAL HUMANO

QREN QUADRO DE REFERÊNCIA ESTRATÉGICO NACIONAL

UNIÃO EUROPEIA
Fundo Social Europeu

Abstract

Although a considerable amount of the scientific works focused on playing position variation of performance characteristics in young soccer players, goalkeeper profiling provided inconsistent findings. From the available data, comparisons are found by selection, competitive level or progressing to higher standards of play. Nevertheless, goalkeepers are a particular population among soccer players, being highly specialized according to their game demands. Thus, this doctoral thesis focused on improving our understanding of performance-related characterization of young soccer goalkeepers, using a multidisciplinary approach. For this purpose, four studies were carried out; three related to the assessment of field-based performance, and one related to laboratory evaluation of short-term maximal efforts. A fifth study was conducted with physical education students, serving as pilot study for the laboratory-based assessment.

The profiling of young soccer goalkeepers stressed that: (*i*) fat mass, agility, aerobic endurance, dribbling speed, shooting accuracy and passing were affected by the gradient derived from the classification between goalkeepers and outfield players; (*ii*) discriminant analysis was able to correctly classify the playing position in the U-13 and U-15 age group based on passing, shooting accuracy, fat-free mass and dribbling speed; (*iii*) a function of four variables – passing, shooting accuracy, ball control and dribbling speed – successfully predicted 100% of players according to playing position in the U-17 and U-19 age group; (*iv*) multilevel regression analysis of aerobic performance, dribbling speed and passing development showed that chronological age was a consistent source of variation as one year predicts improvements in the performance scores of 192.5 m (279%), 0.35 s (26%) and 1 point (41%), respectively; (*v*) the multilevel models also showed that a training enhancement of 1000 h predicts 3 s and 5 points of improvement in soccer-specific skills in young goalkeepers aged 11–18 years.

The specific nature of goalkeeping highlights the importance of short-term efforts and the comparison of laboratory-based measures revealed that: (*i*) goalkeepers competing at a national youth level differed from those competing at a regional level in WAnT mean output, knee flexors at $60^{o}{\cdot}s^{-1}$ and $180^{o}{\cdot}s^{-1}$, and in the conventional ratio at $180^{o}{\cdot}s^{-1}$; (*ii*) a linear combination of three predictors – training experience, ratio knee flexors to knee extensors at $180^{o}{\cdot}s^{-1}$ and WAnT pedal velocity – was able to correctly predict 87.9% of goalkeepers into the original groups; (*iii*) previously, the

reproducibility of estimated optimal outputs was demonstrated using a series of 3 to 5 maximal bouts of 10 s against a range of braking forces on a cycle ergometer.

The great novelty of this research was the design of the Sprint-Keeper Test and the Lateral Shuffle-Keeper Test to examine goalkeeper-specific technique, ensuring that: (*i*) both tests showed good reliability (reliability coefficients > 0.88, intra-class correlation coefficient > 0.908 and coefficients of variation < 4.37%), even though participants tended to improve performance when diving to their right side ($p < 0.05$); (*ii*) mean performance in the two trial sessions was largely associated to acceleration; (*iii*) multivariate analysis of covariance noted a significant effect of competitive level (elite *vs* non-elite), particularly for the left side in both protocols.

Overall, it was believed that this multidisciplinary approach offers a more comprehensive understanding of the dynamic nature of selection and development in young soccer goalkeepers. However, it is recognized that a prospective analysis of this collective work raised new and challenging questions for practitioners involved in applied sciences. A dynamic model of performance characteristics in goalkeepers is presented, based on the continuous interactions of spatio-temporal pattern recognition, decision making and effective skilful movements. Coaches, trainers and other agents involved in youth soccer programs are strongly encouraged to review their goalkeeper-specific training curriculum and methodologies, when available, providing opportunities to optimize an individuals' potential. In conclusion, more than providing straightforward answers and definite conclusions, this thesis raised new questions and opened a challenging new way for approaching goalkeeping performance characteristics.

Keywords: Talent Identification and Development · Football · Sports Training · Playing Position · Sport Specialization · Competitive Level · Growth·Skills · Multilevel Modelling · Reliability · Short-Term Maximal Efforts · Field testing · Diving save

Resumo

Embora uma quantidade considerável de trabalhos científicos evidencie a variação associada à posição das características de performance em jovens jogadores de futebol, a criação de um perfil do guarda-redes tem revelado resultados inconsistentes. A partir dos dados disponíveis, as comparações estabelecem-se considerando a seleção, o nível competitivo ou a progressão para níveis mais elevados. No entanto, os guarda-redes são uma população muito particular entre os jogadores de futebol, sendo altamente especializados de acordo com as suas exigências de jogo. Assim, esta tese de doutoramento pretendeu melhorar a nossa compreensão acerca da caracterização dos fatores de performance em jovens guarda-redes de futebol, utilizando uma abordagem multidisciplinar. Para este efeito, foram realizados quatro estudos: três relacionados com a avaliação de terreno da performance, e um relacionado com a avaliação laboratorial de esforços maximais de curta-duração. Um quinto estudo foi conduzido com estudantes de educação física, apresentando-se como estudo piloto para a avaliação laboratorial levada a cabo.

A determinação do perfil de jovens guarda-redes de futebol salientou que: (*i*) a massa gorda, agilidade, resistência aeróbia, velocidade de drible, precisão de remate e a capacidade de passe foram afetados pelo gradiente derivado da classificação entre guarda-redes e jogadores de campo; (*ii*) a análise discriminante foi capaz de classificar corretamente a posição em campo no grupo formado por jogadores Sub-13 e Sub-15 com base na capacidade de passe, precisão de remate, massa isenta de gordura e velocidade de drible; (*iii*) uma função de quatro variáveis – capacidade de passe, precisão de remate, controlo de bola e velocidade de drible – previu com um sucesso de 100% a posição em campo no grupo de jogadores Sub-17 e Sub-19; (*iv*) a análise de regressão multinível da performance aeróbia, velocidade de drible e capacidade de passe mostrou que a idade cronológica foi uma fonte de variação consistente, na medida em que um ano prevê uma melhoria de 192.5 m (279%), 0.35 s (26%) e 1 ponto (41%), respetivamente; (*v*) os modelos multinível mostraram ainda que o acréscimo de 1000 h de treino prevê uma melhoria de 3 s e 5 pontos nas habilidades específicas de futebol em jovens guarda-redes com idade entre os 11 e os 18 anos.

A natureza específica da atividade do guarda-redes durante um jogo de futebol realça a importância dos esforços de curta duração, e a comparação de medidas

laboratoriais revelou que: (*i*) os guarda-redes que competem a um nível nacional diferem daqueles que competem a nível regional no WAnT mean power, flexores do joelho a 60º·s^{-1}e 180º·s^{-1} e no rácio convencional a 180º·s^{-1}; (*ii*) uma combinação linear de três preditores – experiência de treino, rácio entre flexores e extensores do joelho a 180º·s^{-1}e velocidade no WAnT – foi capaz de corretamente prever 87.9% dos guarda-redes nos seus grupos originais; (*iii*) previamente, a reproducibilidade dos resultados ótimos estimados em ciclo ergómetro foi avaliada, usando uma série de 3 a 5 ensaios de intensidade máxima durante 10 s contra uma carga variável.

A grande novidade trazida por esta pesquisa foi a elaboração do Sprint-Keeper Test e do Lateral Shuffle-Keeper Test para avaliar a técnica específica do guarda-redes, assegurando que: (*i*) ambos os testes apresentaram uma boa fiabilidade (coeficientes de fiabilidade > 0.88, coeficiente de correlação intraclasse > 0.908 e coeficientes de variação < 4.37%), apesar dos participantes tenderem a melhorar o seu desempenho quando realizavam a queda para o lado direito ($p < 0.05$); (*ii*) a performancemédia nas duas sessões de avaliação estava associada à aceleração; (*iii*) a análise multivariada da covariância revelou um efeito significativo do nível competitivo (elite *vs* não-elite), particularmente para o lado esquerdo em ambos os protocolos.

No geral, acredita-se que esta abordagem multidisciplinar oferece uma compreensão mais abrangente da natureza dinâmica dos processos de seleção e desenvolvimento de jovens guarda-redes de futebol. No entanto, reconhece-se que uma análise prospetiva deste trabalho coletivo levantou novas questões para os profissionais envolvidos nas ciências aplicadas. Um modelo dinâmico das características de performance no guarda-redes é apresentado, com base nas interações contínuas do reconhecimento de padrões espácio-temporais, tomada de decisão e movimentos hábeis e eficazes. Técnicos, treinadores e outros agentes envolvidos em programas de futebol para jovens são fortemente encorajados a rever os seus currículos e metodologias de treino específico de guarda-redes, quando estes estão disponíveis, de forma a proporcionar oportunidades para otimizar o potencial individual. Concluindo, mais do que apresentar respostas diretas e conclusões definitivas, esta tese abriu novos e desafiantes caminhos para abordar as características de performance no guarda-redes.

Palavras-chave: Identificação e Desenvolvimento de Talentos · Futebol · Treino Desportivo · Posição de Jogo · Especialização Desportiva · Nível Competitivo ·

Crescimento · Habilidades Motoras · Modelação Multinível · Fiabilidade · Esforços Maximais de Curta-Duração · Testes de Terreno · Técnica de Defesa Lateral

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List of Abbreviations

5JT	–	5-Jump Test
ANCOVA	–	Univariate analysis of covariance
ANOVA	–	Univariate analysis of variance
APHV	–	Age at peak height velocity
B / T / H	–	Chances of beneficial, trivial and harmful differences
CA	–	Chronological age
CI	–	Confidence intervals
CMJ	–	Countermovement jump
CV	–	Coefficient of variation
CYSP	–	The Coimbra Youth Soccer Project
ES-*r*	–	Effect size correlation
Fb	–	Braking force
FFM	–	Fat-free mass
FM	–	Fat mass
FVT	–	Force-velocity test
GPS	–	Global Positioning System
GK	–	Goalkeeper
ICC	–	Intraclass correlation coefficient
IMA	–	Inertial Movement Analysis
$\mathbf{KE_{cc}}$	–	Knee extensors, concentric mode
$\mathbf{KF_{cc}}$	–	Knee flexors, concentric mode
$\mathbf{KF_{cc} / KE_{cc}}$	–	Ratio knee flexors to knee extensors
LOA	–	Limits of agreement
LS-Keeper	–	Lateral Shuffle Keeper-Test
OF	–	Outfield player
OFb	–	Estimated optimal braking force
PMH	–	Predicted mature height
PT	–	Peak torque
rpm	–	Pedal velocity

R	–	Model correlation coefficient
r	–	Pearson's coefficient correlation
RAS	–	Reaction and Action Speed Test
RSA	–	Repeated-sprint ability
S-Keeper	–	Sprint-Keeper Test
SA	–	Skeletal age
SD	–	Standard deviation
SE	–	Standard error
SWD	–	Smallest worthwhile difference
TEM	–	Technical error of measurement
TEOSQ	–	Task and Ego Orientation in Sport Questionnaire
U	–	Under
VIF	–	Variance inflation factor
vs	–	Versus
WAnT	–	Wingate Anaerobic Test

Chapter 1

General Introduction

1.1. Background

The need to improve team and individuals' performance presents itself as both challenging and crucial for coaches. Within this performance-enhancing role, the contribution of those working in the field of sports science is becoming widely recognized as vital for the identification and optimization of the key elements of performance. However, and unlike individual sports, where there is a definitive index of each athlete performance like time or distance, in team sports there are no objective, specific and reliable means of performance assessment (Christopher Carling, Reilly, & Williams, 2009).

Following the ergonomics model for the soccer training process suggested by a renowned author (Reilly, 2005), the game can be considered the main frame-of-reference for performance in soccer. In this extent, applied science can help coaches match the individual's characteristics to the game's demands, thus enhancing player's contribution to team effort. However, the prediction of performance during a match-play based on general and soccer-specific capacities is limited by its own complex nature during competition (Svensson & Drust, 2005). While *"sport scientists are used to dealing with precise, quantifiable, numerical data, and although these are indicators of an athlete's potential to perform, actual performance within a team-sport framework is still a relatively abstract concept"* (Mujika, 2007). Soccer performance is, in fact, a construct based on many different performance components and their interaction at both individual and collective level (Drust, Atkinson, & Reilly, 2007), requiring the individual team members' harmonization into an effective unit to achieve the desired outcome (Reilly, 2001). The proficiency of a player's actions during a soccer match is determined by the response to physiological, technical, tactical, cognitive and psychological stressors under a high situational unpredictability.

Soccer is an intermittent sport with a predominance of the aerobic system, including frequent bouts of activity (Bangsbo, 1994). The requirements for soccer player are multifactorial, involving a great variability in the activity and recovery periods, with constant fluctuations in intensity and duration. Players are required to perform a multiplicity of movement patterns (forward, lateral, backward), activity profiles (e.g., from jogging to sprinting), explosive technical actions (kicking, tackling, diving), sustained forceful actions to control the ball against defensive pressure, and to react under great time pressure, involving countless perceptual cognitive efforts.

While there is no clear relationship between test measures and actual competitive performance, the assessment of players' performance characteristics is widely used in both research and applied contexts (Drust et al., 2007). Attempts to identify and evaluate soccer performance components occur in challenging settings for researchers. An insightful balance between a comprehensive control of key experimental variables and ecological validity of measurements is required when testing soccer players. Whether performance assessment is field or laboratory-based, it's most important that research designs can be translated into practical applications and collaborative investigations can be undertaken by researchers, sport-sciences practitioners and coaches (Bishop, 2008). A summary of the main reasons and purposes of testing and assessing performance characteristics in soccer players is presented in Table 1.1.

Table 1.1. Reasons for assessing performance in soccer.

Individual and team profile	Rehabilitation and health	Talent identification and development
To establish a baseline profile for individual players and team. To identify individual strengths and weaknesses. To provide feedback to players and act ergogenically by influencing their motivation to improve. To evaluate objectively the effectiveness of specific training interventions.	To evaluate objectively the effectiveness of training-related interventions. To monitor progress and readiness for competing. To monitor health status of a player.	To assist in identifying talented players. To attempt to create normative values according to age category, stage of development, competitive level and playing position. To monitor and evaluate the progression of youth players. To place players in an appropriate training group. To examine the developmental changes. To enable future performance to be predicted. To provide data for scientific research on the limitations of performance.
Identification, adaptation and optimization of training and coaching programs.		

Adapted from (Christopher Carling et al., 2009).

1.2. Match-performance

The internal and external loads imposed on elite players during a soccer match are of intermittent and variable nature. Players are required to perform different types of movements with a wide range of intensity and frequent turns (Bloomfield, Polman, & O'Donoghue, 2007; Stolen, Chamari, Castagna, & Wisloff, 2005). Distances covered at top level are in the order of 10000–12000 m for outfield players (Di Salvo et al., 2007; Stolen et al., 2005) and 5611 m for goalkeepers (Di Salvo, Benito, Calderon, Di Salvo, & Pigozzi, 2008). Within this aerobic context, positional differences are also evident (Di Salvo et al., 2007), with central and external midfielders covering a significantly greater total distance than forwards, central and external defenders.

After a substantial increase in the physical demands observed in competition up until the early years of the 21st century (C. Carling, 2013), total distance covered during a match was, in the English Premier League, ~2% lower in 2006-07 when compared to 2012-13 (Barnes, Archer, Hogg, Bush, & Bradley, 2014). On the other hand, across seven seasons, high-intensity running distance and actions increased by ~30% and ~50%, respectively. Sprint distance and number of sprints increased by ~35% and 85%. Even though considerable between-match variability of total high-speed running distance (17.7±6.8%), high-speed running distance (16.2±6.4%) and total sprint distance (30.8±11.2%) have been observed in 485 players competing in the English Premier League (Gregson, Drust, Atkinson, & Salvo, 2010), time motion analyses have contributed to highlight the importance of short-term maximal efforts in soccer.

Although the requirements of different youth soccer codes do not tally the activity patterns and physical demands information regarding elite players (Tessitore et al., 2012), it's fair to assume that match metrics do not fully resemble individual player metrics in both youth and professional levels. Yet, and as an example,by increasing the available force of muscular contraction in appropriate muscles or muscle groups, we can expect an enhancement in soccer-related activities like acceleration, speed, jump, change of direction, kicking or tackling. Accordingly, a relationship between muscle strength and sprint performance and vertical jump height was verified in elite players (Wisloff, Castagna, Helgerud, Jones, & Hoff, 2004). Nevertheless, there are other important aspects to consider besides the physiological characteristics, such as soccer-specific and motor coordination skills (Vandendriessche et al., 2012).

1.3. Multidisciplinary approaches in youth soccer

An important feature of performance assessment in youth soccer is the identification and development of talented players. Talent identification refers to the process of recognizing current participants with the potential to excel in a particular sport, while talent development implies that players are provided with the most appropriate learning environment so that they have the opportunity to fulfil their potential (Williams & Reilly, 2000). Finally, the concept of talent selection is related to the ongoing process of choosing the player or team with the ability to perform best within a specific context, at any given stage. Sport sciences have therefore, an important supporting role in the process of identifying, monitoring and nurturing talented soccer players (Vaeyens, Lenoir, Williams, & Philippaerts, 2008; Williams & Reilly, 2000) by helping them towards fulfilling their potential.

Multidisciplinary approaches should be adopted to identify the key outcome measures in youth soccer with greater precision, and provide templates for viewing talent development systems in a more objective way (Reilly, Williams, Nevill, & Franks, 2000; Stratton G, 2004). Typically, these approaches are based on a limited number of characteristics, such as anthropometric, physiological, technical, tactical and psychological (Elferink-Gemser, Visscher, Lemmink, & Mulder, 2004; Vaeyens et al., 2006), each one of these constructs having a different effect in the development of a successful career. Even within a more homogeneous sample of talented soccer players (Huijgen, Elferink-Gemser, Lemmink, & Visscher, 2014), multidimensional performance characteristics were able to discriminate between selected and deselect players. Still, the importance of anthropometric and physiological determinants might be improved by moving towards a more game-specific protocol, in which multiple small-sided games are considered as an acting tool (greater ecological validity) for talent identification (Unnithan, White, Georgiou, Iga, & Drust, 2012).

Ultimately, talent must be seen as a dynamic concept or a long-term prediction in which we project a young athlete's future performance. A study carried out in Germany (Gullich, 2014) found that most of the young players selected at a particularly age were often replaced within a short time by others who had developed more prosperously outside the youth academies and national U-teams, usually a substantial annual turnover. As a matter of fact, only 7% of players remained members in the youth elite academies (U-10 to U-19), while 35.6% played for national junior teams from U-15 to U-18. Therefore, there are no guarantees that an early engagement in long-term programs leads to successful levels of performance, as players are continuously subjected to repeated procedures of selection and deselection. It has been suggested that discriminating characteristics in youth soccer players vary by age group (Vaeyens et al., 2006). Stepwise discriminant analyses from the Ghent Youth Soccer Project showed that running speed and technical skills were the most important characteristics in U-13 and U-14, while cardiorespiratory endurance was more significant in U-15 and U-16. The impact of growth and maturation on the readiness of youngsters also needs to be considered, as well as its effects on specialization by playing position (Stratton G, 2004).

1.4. Age-related variation

During childhood and adolescence, subjects experience the interaction of three different processes: growth, maturation and development (Malina R., 2004). Accordingly, a considerable variation is manifested within and between subjects in body size, composition, proportions, biological maturation and motor development, as these processes vary in intensity and timing. The mean heights and weights from a series of studies of young soccer players from about 9 to 18 years of age in Europe and Americas tend to fluctuate above or below the reference medians for general population during childhood and early adolescence (Malina, 2003). However, players in later adolescence tend to have, on average, more weight-for-height. A boy is expected to gain about 14 kg of fat-free mass and 1.5 kg of fat mass during peak height velocity (Malina R., 2004).

A mismatch between the specific tasks of normal growth and maturation and the demands of a sport discipline is quite common, with critical influences on coaches and administrators perspectives' regarding subjects sport-related behaviours and performance (Figueiredo, Coelho, Cumming, & Malina, 2010). The Portuguese Soccer Federation, for instance, provides a 2-year age group organization in youth soccer, as follows: under-11 (U-11; 9–10 years old); under-13 (U-13; 11–12 years old), under-15 (U-15; 13–14 years old), under-17 (U-17; 15–16 years old), and under-19 (U-19; 17–18 years old). By simply getting older, significant attainment advantages might be provided to older players compared to those who are chronologically younger.

Applied research in youth soccer has provided reasonable findings relating growth, maturity status, physiological capacities and skills (Reilly, Williams, et al., 2000; Stratton G, 2004). A gradient of U-18 > U-16 > U-14 was found in acceleration, maximum running sprint and repeated-sprint performance among 61 highly trained young male soccer players (Mendez-Villanueva et al., 2011). Similar findings were found for repeated-sprint ability from U-11 to U-15 age groups in 134 youth players (Mujika, Spencer, Santisteban, Goiriena, & Bishop, 2009). Although no significant improvements were found from U-15 to U-18, these age-related differences were strongly correlated with height, weight and the glycolytic potential of the players. Similar to what was previously suggested, if we consider more homogeneous player groups, it's unlikely that differences in body size will substantially explain the superior performance of older and/or international players (Buchheit et al., 2013).

Another related aspect to consider when organizing soccer competitions using chronological age-based standards is overrepresentation of youth and professional players who are born early in the selection year (Helsen et al., 2012; Vaeyens, Philippaerts, & Malina, 2005; Votteler & Honer, 2014). This same trend, often referred as relative age effect, was recently found among 374 elite Belgian youth soccer players (Deprez et al., 2013). Actually, 42.3% of the players were born in the first birth quarter, while only 13.7% were born in the fourth birth quarter. Interestingly, this study revealed no differences in anaerobic parameters after controlling for age and age at peak height velocity (APHV). In this sense, and for our research purposes, focus should be placed in the athlete's potential to become an expert, assembling a group of internal and external factors accomplished by a set of superior master behaviours on a given time and tempo.

1.5. Maturity-related variation

The elite soccer context is highly selective and exclusive, particularly as chronological age and specialization of the game increase. Soccer systematically excludes late mature athletes in relation to those situated on the average and, especially, early maturing boys. Across the age groups coincident with interval of maximum growth in height (i.e., U-13 – U-16 age categories), players advanced in maturation tend to be larger in terms of body size (Figueiredo, Gonçalves, Coelho e Silva, & Malina, 2009b; Malina, Eisenmann, Cumming, Ribeiro, & Aroso, 2004; Vaeyens et al., 2006). They also tend to attain better scores in explosive performance given by the vertical and standing long jump, sprinting (Malina et al., 2004; Vaeyens et al., 2006), agility and endurance performance (Vaeyens et al., 2006) than late mature players. Conversely, players of contrasting maturity status do not consistently differ in sport-specific skills (e.g., ball control, dribbling, passing and shooting) (Figueiredo et al., 2009b; Malina et al., 2005) and non-specific motor coordination tests (Vandendriessche et al., 2012).

Biological maturation is often assessed by skeletal age, secondary sex characteristics and somatic indicators such as percentage of adult height and maturity offset. Based on a multiple regression analyses, maturity was a significant source of variation in physiological performance (Malina et al., 2004) and contributed positively, although in a small extent, to sport-specific skills in 13- to 15-year-old soccer players (Malina et al., 2005). More precisely, the stage of pubic hair accounted for 18% in the Yo-Yo intermittent endurance test, 49% in counter-movement jump, 39% in 30m sprint, 10% in ball control with the body and head, 19% in dribbling speed with pass, and 5% in shooting accuracy, along with training experience, weight and height. Skeletal maturity was considered in a study with 143 soccer players and represented two age groups, 11–12 years old and 13–14 years old (Figueiredo, Coelho e Silva, & Malina, 2011). This maturity indicator was among the predictors of the counter-movement jump in both age groups (22% and 36%, respectively), and of the physiological (58%) and skill composite (16%) scores in the older group.

Advanced-maturity players are often selected to certain playing positions based on larger body sizes, higher levels of strength and power. Predicted age at peak height velocity (APHV) had a small to moderate effect between defensive positions (goalkeepers and defenders) and more attacking positions (midfielders and attackers) among high-level youth soccer players from U-11 to U-17 (Deprez et al., 2015). Finally, results of somatic indicators (Gil et al., 2014), given by an earlier maturity offset and APHV and higher percentage of predicted mature height, revealed large differences between selected and non-selected goalkeepers.

Thus, the considerable age-related variation in body size and maturity status appears to be significantly different by age group and even by playing position. Although early advanced players tend to dominate the game during early adolescence, opportunities for late developers to catch up and optimize their potential should be provided. An 8-year follow-up study (Ostojic et al., 2014) suggested that elite soccer competences are achieved more often by those who were late mature at age 14 (60.1%), than average matures (38.1%) and early matures (11.8%).

1.6. Position-related variation

A consistent body of literature seems to support the hypothesis that a particular profile is required by different playing positions both at youth and professional levels. In fact, professional adult goalkeepers are taller and heavier than their counterparts, usually over 180 cm tall and 77 kg heavy (Ziv & Lidor, 2011). Among elite Croatian soccer players, goalkeepers were also older and more experienced (Sporis, Jukic, Ostojic, & Milanovic, 2009). Their aerobic capacity is consistently lower than defenders, midfielders and forwards (Boone, Vaeyens, Steyaert, Vanden Bossche, & Bourgois, 2012; Reilly, Bangsbo, & Franks, 2000). Vertical jump is regularly seen as an important feature at a professional level (Boone et al., 2012; Sporis et al., 2009; Stolen et al., 2005). Thus, it is fair to assume that particular anthropometric and physiological prerequisites are important to become a professional soccer goalkeeper.

A specific profile for each particular playing position seems to be already identifiable in youth soccer players, particularly when it comes to select a child or an adolescent to play as goalie. Goalkeepers consistently tended to be taller, heavier, with higher values in the fat component such as body mass index, fat mass percentage and skinfolds (Gil, Gil, Ruiz, Irazusta, & Irazusta, 2007; Lago-Peñas, Casais, Dellal, Rey, & Dominguez, 2011; Wong, Chamari, Dellal, & Wisloff, 2009). Interestingly, there are no common physiological differences in the specialization of goalkeepers except for aerobic protocols, like the Astrand test (Gil et al., 2007) and the 20 m progressive run test (Wong et al., 2009), in which they exhibited the poorest performances. Laboratory-based assessments among 296 Greek youth players revealed that goalkeepers exhibited the highest peak power, though significant differences were only found for mean power relative to body mass and fatigue index (Nikolaidis, 2014). Due to the uniqueness of goalkeeping and its' typical technical actions, alongside their lower ratio within a team when compared to other playing positions, goalkeepers have often been excluded from studies including soccer-specific skills. However, it is plausible to assume that goalkeepers demonstrate poorer performances in skill tests such as the Hoff dribbling protocol (Lago-Peñas et al., 2011).

Body size is very likely one of the most important prerequisites to progress to later stages of development and become a professional goalkeeper. A recent study (Deprez et al., 2015) investigated positional differences in 744 high-level soccer players from U-9 to U-19, and a clear distinction between goalkeepers and outfielders was already manifested from the age of 8 years. Across all age groups, goalkeepers and defenders were the tallest and heaviest compared to the smaller and leaner midfielders and forwards. Also, goalkeepers were the most flexible from the age of U-15 and had the lowest intermittent endurance capacity. It seems that coaches tend to select and specialize young players in a specific position according to their individual anthropometric and physiological characteristics. Still, the question whether the observed differences are a function of coach/trainer selection per se, differential success of taller and heavier players or both remains unclear.

1.7. Variation associated to competitive level

Soccer is predominantly characterized by a hierarchical system that selects a smaller number of players to compete at a higher level of competition, as this increase with time. The performance level of a player is often described by the level of competition (e.g. elite, sub-elite, non-elite, selected, non-selected, local, regional, national, and international). When considering the current level of play and future success, agility, running speed, motivational orientation, anticipation skill (Reilly, Williams, et al., 2000), accumulated practice (Helsen, Hodges, Van Winckel, & Starkes, 2000), height and squat jump (Coelho e Silva et al., 2010), and dribbling speed (Vaeyens et al., 2006) appear to have a strong discriminative power amongst youth soccer players. A retrospective study (Figueiredo, Gonçalves, Coelho e Silva, & Malina, 2009a) reported that elite players at follow up were already larger in body size, more powerful and agile than those who remained at a non-elite level or dropped out at baseline in U-13 and U-15 age categories.

Variation in anthropometric, physiological and skills characteristics among goalkeepers considering current or future level is still limited. Nonetheless, an effect of competitive level in body size is apparent (Gil et al., 2014; le Gall, Carling, Williams, & Reilly, 2010). For instance, U-19 Portuguese elite goalkeepers tended to be taller, heavier and more experienced ($0.6 < d < 1.2$) than non-elite. Important field-based and laboratory-based information showed that elite goalkeepers tended to perform better in the squat jump, Yo-Yo intermittent endurance test – level 2, ball control, 30 m sprint, agility, peak torque of knee extensors and flexors ($d > 1.2$), and countermovement jump ($d > 2$) (Rebelo et al., 2012). A study that included 23 goalkeepers who ultimately joined professional clubs (le Gall et al., 2010) found significantly greater differences for sprint performance, maximal anaerobic power output (derived by the recorded time over the last 10 m of the fastest 40 m sprint) and strength of the knee flexors of both the dominant and non-dominant legs. A large effect was verified between selected and non-selected Spanish goalkeepers (Gil et al., 2014) for handgrip ($d = 0.817$) and countermovement jump ($d = 0.915$). However, our understanding of the identification and optimization of key elements in successful goalkeeping still needs further analysis, since these characteristics might change over time.

1.8. Longitudinal studies

Evidence drawn from longitudinal studies in youth soccer (Mirkov, Kukolj, Ugarkovic, Koprivica, & Jaric, 2010; Philippaerts et al., 2006) suggests that maximal gains in running speed, agility, aerobic endurance, trunk strength, upper and lower limb explosive strength occur, on average, close to the time of peak height velocity (i.e., the period of maximal height gain during the adolescent growth spurt). The intermittent endurance capacity of 492 Dutch players was measured over a 10-year period, resulting in 953 measurements (Elferink-Gemser, Huijgen, Coelho-e-Silva, Lemmink, & Visscher, 2012). Between seasons 2000/2001 and 2009/2010 moderate to large improvements (50% on average) were observed in players from U-13 to U-19. A plausible explanation could be the increase in training hours per week devoted to soccer, since the amount of time dedicated to extra training remained stable over the years. However, analysis of variance results weren't able to explain improvements by ten times in intermittent endurance capacity. Besides, factors regarding training quality, such as coaches' qualifications and players' mechanisms of self-regulation play a very important role in a successful soccer player development.

A growing body of literature in talent development and selection studies has used multilevel modelling analyses to enhance our understanding of developmental changes in sprinting and dribbling (Huijgen, Elferink-Gemser, Post, & Visscher, 2010), passing (Huijgen, Elferink-Gemser, Ali, & Visscher, 2013), soccer-specific aerobic performance (Deprez et al., 2014), and in repeated-sprint ability in players of contrasting maturity status (Valente-Dos-Santos, Coelho, et al., 2012). The multilevel technique is an extension of multiple regression analysis and is suitable for analyzing hierarchically structured data. Briefly, dependent variables are measured within individuals (level 1 of the hierarchy) and between individuals (level 2 of the hierarchy). The final models only include variables that are significant independent predictors.

Longitudinal changes in physiological composite score among male youth soccer players were partially explained by age, maturation, fat mass, training volume and dribbling speed, while age, playing position, fat and fat-free masses, training volume, repeated sprint ability and aerobic endurance entered the model in skill performance (Valente-dos-Santos, Coelho-e-Silva, et al., 2012). Predicted scores for playing position and maturity status aligned by skeletal age and chronological age were similarly presented in change of direction and dribbling speed (Valente-Dos-Santos, Coelho-e-Silva, et al., 2014; Valente-Dos-Santos, Coelho, et al., 2014). Still, literature profiling the soccer goalkeeper across long-term sport preparation is hardy available.

1.9. Mapping the goalkeeper's domain

So far, we've had an overview of the most common literature that includes the goalkeeper, while comparing anthropometric and physiological characteristics and soccer-specific skills. Although there is a considerable amount of research in soccer regarding the variation by playing position, very little is yet known about the specific position of goalkeeper and its distinctive performance characteristics. In reviewing a series of studies (Ziv & Lidor, 2011), authors observed that professional adult goalkeepers are usually over 180 cm tall and have body mass values above 77 kg. Power, strength, speed, agility and aerobic endurance were also considered important attributes when characterizing soccer goalkeepers.

A substantial number of studies examining the penalty kick situation highlighted the ability of expert goalkeepers to more accurately anticipate the outcome of a situation based on the postural movements of their opponents (e.g. fixation duration, number of fixations, and the proportion of time spent fixating different display areas) and pattern recognition (Table 1.2). However, we need to consider that relatively few goals in elite football are scored from penalties; between 2006 and 2012, in the English Premier League (Gelade, 2014), only 7.7% of goals scored were penalty goals, and the rest were scored from regular play or as a result of other set plays. In another study (Dessing & Craig, 2010), it has been reported that human poor sensitivity to visual acceleration makes it harder for expert goalkeepers to perceptually judge where the curved free-kicks will cross the goal line, as they do not fully account for spin-induced lateral ball acceleration and movement errors, resulting in less time to cover a now greater distance to stop the ball from entering the goal.

The evolutionary tendency of the game requires the goalkeeper to excel in a wide range of physical, technical and tactical behaviours, particularly in offensive actions such as distribution and back-pass. Nevertheless, the goalkeeper's specificity relies on his unique defensive role: the use of his hands inside the penalty area. Diving was considered the most common physical action in defensive actions (Sainz de Baranda, Ortega, & Palao, 2008), and deserved some attention through biomechanical and cinematic analysis (Table 1.2). Reliability results of a new test involving several components like sprinting, jumping, diving and changing of direction revealed a variation of intraclass correlation coefficients (ICC) between 0.68 and 0.95 (Knoop, Fernandez-Fernandez, & Ferrauti, 2013). The Reaction and Action Speed test (RAS) was able to identify asymmetries between diving sides, and to observe differences between U-19 first goalkeepers (n = 10) and their substitutes (n = 11). However, the RAS comprises a complex instrumental apparatus that is not easily available to coaches and practitioners.

Table 1.2. A brief summary of scientific research focusing on soccer goalkeepers.

Study	Participants	Purpose	Main results
Penalty kick			
(Kuhn, 1988)	*n*=83 penalty kicks	Observe and analyse the control strategies of both shooters and GKs.	Ball speed was 75 $km.h^{-1}$ and took 600 ms to reach the goal line, on average. GKs had 60% chance of success when movement occurred at the moment of ball contact or immediately afterwards.
(G. J. Savelsbergh, Williams, Van der Kamp, & Ward, 2002)	*n*=7 experts *n*=7 novices	Examine differences in anticipation and visual search behaviour between expert and novice GKs.	The expert group involved fewer fixations of longer duration to fewer areas, preferring to fixate their gaze on the kicking and non-kicking legs and ball areas. The novices spent longer fixating on the trunk, arm and hip regions.
(Bar-Eli, Azar, Ritov, Keidar-Levin, & Schein, 2007)	*n*=286 penalty kicks	To determine whether soccer GKs exhibit the action bias and jump during penalty kicks more than is optimal and explain it.	While the utility-maximizing behavior for GKs is to stay in the goal's center during the kick, in 93.7% of the kicks the GKs chose to jump to their right or left. This non-optimal behavior suggests that a bias in GKs decision making might be present.
(G. Savelsbergh, van Gastel, & van Kampen, 2010)	*n*=30 inexperienced GKs	Improve the estimation of the direction of the ball during penalty kicks by changing the visual search behaviour.	The perceptual learning group significantly changed their visual search behaviour, improving the initiation of the joystick movement. This group was also more successful in stopping penalty kicks than the training and control groups.
(Wood & Wilson, 2010)	*n*=18 university footballers	Examine the effect of GKs distracting strategies on the attentional control and performance of penalty shooters.	Significantly more penalties were saved on trials when the GK was moving and shots were also generally hit closer to the GK (centrally) on these trials. GKs may benefit from distracting the penalty takers, especially during the aiming phase.
(Dicks, Uehara, & Lima, 2011)	Review	Discuss findings and practical implications in visual and anticipation research.	GKs will benefit from using late information that emerges just before the initiation of the penalty kicking action (450 ms before football contact). Practice variability under changing conditions may facilitate learning and accuracy in anticipation.
(Lidor, Ziv, & Gershon, 2012)	Review	Discuss findings, research limitations, methods and practical implications.	GKs can improve their chances through anticipation, deception strategies and tactical behaviours. Training should focus on reaction and movement.
(Peiyong & Inomata, 2012)	*n*=12 GKs *n*=12 OFs	Examine how a GK response-initiation time influences the response accuracy.	Gks had a significant faster response-initiation time than the outfielders and were more likely to adopt a strategy of relying on situational probabilities.

Table 1.2. A brief summary of scientific research focusing on soccer goalkeepers (continuation).

Match-performance	Participants	Purpose	Main results
(Di Salvo et al., 2008)	*n*=62 in a total of 109 matches	Analyse the activities of GKs during a match from 28 teams in the English Premier League.	Total distance (m) 5611±613, CV=10.9%. High-speed run: 10±6, 56±34 m, CV=61.2%. Sprint: 2±2, 11±12 m, CV=104.2%. Walking 73% of the time and 2% moving at high-intensity.
(Sainz de Baranda P., 2008)	*n*=34 in a total of 54 matches	Examine the characteristics of the GKs defence intervention during the 2002 FIFA World Cup.	Defensive technical actions per match: 23.4; save (9.96±3.8), foot control (6.5±4.2) and clear out (2.9±1.8). Physical actions: dive (6.2±2.7), jump (3.8±2.3) and displacement (18.7±6).
(Padulo, Haddad, Ardigo, Chamari, & Pizzolato, 2015)	*n*=10 *n*=5 Serie C *n*=5 Serie D	Quantify actions and sprints in professional Italian soccer GKs by a high-speed video analysis.	270±162.6m high intensity distance covered, and 92 high intensity actions (52 forward and 40 lateral). GK-C performed a larger number of actions and were faster in the last meter.
Diving technique			
(Suzuki, Togari, Isokawa, Ohashi, & Ohgushi, 1987)	*n*=4	To analyse the goalkeeper's diving motion by cinefilm analysis.	A more efficient diving involves a lower centre of mass, flexed hips and knee joint and a direct movement to the ball.
(Sørensen, Thomassen, & Zacho, 2008)	*n*=6	To investigate if skill level correlates to a number of biomechanical tests.	No differences were noted for the vertical and horizontal jumping ability, reaction time and short-sprint time.
(Spratford, Mellifont, & Burkett, 2009)	*n*=6 elite U20	Biomechanical examination of movement patterns in diving according to side preference.	Asymmetries were verified with a greater lateral rotation of thorax and pelvis (initiation event). Hip kinematics, peak joint moments and centre of mass were consequently influenced in the take-off and ball contact phases.
(Schmitt, Schlittler, & Boesiger, 2010)	*n*=8	To assess hip loading during side jumps.	GKs performing a rolling motion reduced their hip loading.
(Hervéou, Rahamni, Boyas, Chorin, & Durand, 2015)	*n*=10	To investigate the mechanical and neurophysiological processes in diving.	Knee extensors and plantar flexors were the most activated muscles followed by the ankle dorsiflexors and knee flexors. Importance of the contralateral leg at the beginning of diving movement.

1.10. Rationale, purpose and outline of the thesis

Sport sciences have an important supporting role in the processes of identifying, monitoring and nurturing talented soccer players towards realising their potential. However, given that performance in soccer is multifactorial and a relatively abstract construct (Christopher Carling et al., 2009; Mujika, 2007; Pyne, 2012), there is still plenty to know about talent identification, selection, specialization and development in youth soccer. Additionally, multidisciplinary studies are highly recommended in sports performance and there is much to be gained by taking a broader collaborative approach (Pyne, 2012), especially in times of financial constraints and scientific competitiveness.

To date, studies examining the anthropometrical, physiological and soccer-specific skills provided certain markers for predicting those individuals who have a reasonable chance to succeed at a later stage of development (Figueiredo et al., 2011; Malina et al., 2005). Higher values of height and body mass have been related to superior motor achievements (Figueiredo et al., 2009b; Malina et al., 2005; Malina et al., 2004; Vaeyens et al., 2006). Among 69 male youth soccer players, maturity status (positive) and height (negative) had a significant influence on the composite skill score, accounting for 21% of the variance (Malina, Ribeiro, Aroso, & Cumming, 2007). When physiological measures were included in the multiple linear regression analysis, aerobic resistance (positive) added 8% to the total explained variance.

Based on the assumption that changes in specific performance characteristics are mostly affected by growth and maturation, their trainability needs to be thoroughly scrutinized in order to identify the relative effects of training during childhood and adolescence. Moreover, coaches are challenged to recognise the contribution of these confounding variables, as they might be responsible for the large intra- and inter-individual variation on a given time measurement. Information on longitudinal changes can, when available, improve our understanding of the factors that contribute to performance improvements, and their variation associated with chronological age, biological maturation, competitive level and playing position. The Ghent Youth Soccer Project examined the relationships between growth and performance (Philippaerts et al., 2006). Data from this 5-year mixed-longitudinal study revealed that running speed and technical skills were the most important characteristics that discriminated U-13 and U-14 players, while cardiorespiratory endurance was more significant in U-15 and U-16 players (Vaeyens et al., 2006).

Different anthropometric and physiological characteristics are required for a specific tactical position since youth, and each position has qualitatively different soccer-specific aspects related to it. Forwards and defenders were skeletally more mature than midfielders in the U-17 Portuguese national team (Malina et al., 2000). In a contrasting trend, forwards appeared to have proportionally more weight for height (Malina et al., 2004) among players aged 13–15 years old, whereas position had a negligible effect in U-14 players (Coelho e Silva et al., 2010). Although position-related variation has deserved a considerable attention in scientific research, very little is known about the specificity of goalkeeping in youth soccer. Indeed, the goalkeeper is often neglected in data collection and analysis, reflecting a gap that applied sciences should strive to fill.

It is widely accepted that goalkeeping is predominantly anaerobic in nature. During match-play, goalkeepers spend 73% of the time walking and only 2% moving at high-intensity (Di Salvo et al., 2008). During these short-burst periods, goalkeepers are usually required to perform specific offensive and defensive actions, according to the contextual dimension. The existing studies focusing on goalkeepers covered dispersed aspects, mostly related to penalty kick situations (Lidor et al., 2012; G. J. Savelsbergh et al., 2002) and diving actions (Schmitt et al., 2010; Spratford et al., 2009). Available data consistently reported the goalkeeper as being taller and heavier, with higher values of fat component than midfielders and forwards (Gil et al., 2007; Lago-Peñas et al., 2011). They also tend to be outperformed by all their counterparts in aerobic protocols (Wong et al., 2009) and to be the most flexible (Deprez et al., 2015). It can be empirically assumed that change of direction, reactive agility, power, speed and jumping are also important elements in successful goalkeeping. However, profiling goalkeepers at younger ages is still a rather irrelevant matter in applied research.

Multidisciplinary studies need to include goalkeeper-specific measures, since hardly any information exists regarding technical demands. In fact, only one study adopted specific measures to assess goalkeeping performance (Knoop et al., 2013), which is clearly scarce. Besides the abovementioned limitations, the lack of a longitudinal approach, of on-field data, of experimental studies, and the shortfall of reporting on effect sizes and observed power have been pointed out as main methodological limitations and research concerns (Ziv & Lidor, 2011) regarding performance-related measurements of goalkeepers.

Therefore, the overall purpose of this thesis is to improve our understanding of performance characteristics in young soccer goalkeepers, using a multidisciplinary approach. Particularly, the current report describes biological maturation, anthropometric and physiological characteristics, soccer-specific and goalkeeper-specific skills in accordance with playing position, competitive level and age-related variation.

The thesis is presented in manuscripts format, organized in three main chapters (**Chapter 3** to **5**), in an attempt to measure components that represent the specificity of goalkeeping performance through a multidisciplinary approach. **Chapter 3** comprises both cross-sectional and longitudinal multidimensional characterization of young soccer goalkeepers. The f**ourth chapter** includes a laboratory-based assessment of short-term maximal efforts in goalkeepers of different levels. Finally, **Chapter 5** focus on goalkeeper-specific testing. Each of these chapters is composed of manuscripts previously published or submitted for publication, sharing a common structure with minor modifications according to journal guidelines. A total of five manuscripts are presented, each addressing a specific component of the overall purpose of this thesis.

After an overview of literature and a proper contextualization of the research theme in **Chapter 1**, **Chapter 2** describes methods and procedures adopted in order to study each of the research questions. **Study 1** was already published elsewhere (Rebelo-Goncalves, Coelho-e-Silva, Severino, Tessitore, & Figueiredo, 2015), while **study 4** is under revision. **Studies 2**, **3** and **4** have been submitted to peer review international journals with impact factor.

Chapter 3 focuses on the anthropometric, physiological and skills profiling of young soccer goalkeepers. The cross-sectional study examines age and position-related variation considering body size and composition, biological maturation, physiological capacities, soccer skills and the features that may distinguish the goalkeeper from outfield players. The longitudinal study explores the above mentioned variables as predictors of developmental changes in aerobic performance, dribbling speed and passing skills among goalkeepers.

Chapter 4 examines the variation of maximal intensity short-term performance between goalkeepers playing at national and regional levels. Laboratory-based assessments included isokinetic dynamometry, the Wingate Anaerobic Test and a force-velocity test performed on a friction-braked ergometer. Although the force-velocity test provides a promising model for assessing peak outputs, the test-retest reliability has not been extensively documented. Santos, Welsman, De Ste Croix, and Armstrong (2002) reported mean values for optimal peak output of 472.1–133.6 W at test session 1 and 493.5–149.5 W at test session 2. Results for the reliability in 41 pre-teenage boys and girls aged 9–10 years also showed a mean CV of 3.0%, while a reliability coefficient of 51 W (95% limits of agreement of 16.68–38.2 W) was calculated. In addition, the effect of the protocol on the force-velocity test and warm-up procedures needs to be considered and examined (Driss & Vandewalle, 2013). For these reasons, a pilot study was intended to examine the reproducibility of estimated peak output and estimated pedal velocity derived from a force-velocity test on a cycle ergometer.

In **Chapter 5**, a better understanding regarding performance-related characterization of soccer goalkeepers is promoted through the development and evaluation of two new goalkeeper-specific tests. Accordingly, the S-Keeper Test and LS-Keeper Test were evaluated for their reliability and validity.

Finally, the major findings of this thesis are summarized and discussed in **Chapter 6**. Future research and practical implications are also addressed.

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Chapter 2

Material and Methods

2.1. Study design and sampling

The present thesis includes five studies extracted in part from a research proposal granted and funded by the Portuguese Foundation for Science and Technology (SFRH/BD/72111/2010). **Study 2** was also approved and partially granted by the Portuguese Foundation for Science and Technology [PTDC/DES/121772].The research proposal was conducted in accordance with the ethical principles for medical research involving human subjects ("World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects," 2013), and with the ethical standards for sports medicine (Harriss & Atkinson, 2013).Data collection was conducted using the equipment of two different research units:

1) The Research Unit for Sport and Physical Activity, Faculty of Sport Sciences and Physical Education, University of Coimbra, Coimbra, Portugal (**study 1** to **5**);
2) The Department of Human Movement and Sports Science, University Foro Italico, Rome, Italy (**study 5**).

All participants and parents or legal guardians received a complete explanation about the testing procedures and that they could withdraw from the study at any time before providing written consent. Clubs were also fully informed about the nature of the study, objectives and procedures before authorizing data collection.

Basic characteristics of each study are summarized in Table 2.1. Despite the limited sample size of most of the studies, it should be noted that we dealt with a highly specific population. The low ratio of goalkeepers per team, the voluntary participation of subjects and the age-range usually considered in the studies, are also factors affecting samples homogeneity. Still, the present report represents a first research attempt designed to focus on performance characterization of young soccer goalkeepers.

Table 2.1. Design, conditions, sampling and studied variables involved in each study.

Study	Design	Condition	Sample	Age (years)	Variables
1	Cross-sectional	Field testing	145 young male soccer players	15.08±1.59	Anthropometry; quantitative training-related; biological maturation; physiological characteristics; soccer-specific skills; goal orientation
2	Mixed-longitudinal	Field testing	16 young male soccer goalkeepers; 71 measurements	11–18	Anthropometry; quantitative training-related; biological maturation; aerobic performance; soccer-specific skills
3	Cross-sectional	Laboratorial testing	22 physical education students	23.50±4.73	Anthropometry; body composition; quantitative training-related; maximal intensity short-term performance
4	Cross-sectional	Laboratorial testing	33 young male soccer goalkeepers	15.60±1.90	Anthropometry; quantitative training-related; biological maturation; body composition; maximal intensity short-term performance
5	Cross-sectional	Field testing	26 young male soccer goalkeepers; 40 young male soccer goalkeepers	14.49±2.52 14.49±1.71	Anthropometry; quantitative training-related; maximal intensity short-term performance; goalkeeper-specific technique

2.2. Anthropometric characteristics

Body size

Anthropometric characteristic in **studies 1** to **4** were assessed by a single trained observer following standard procedures (Lohman, Roche, & Martorell, 1988). A portable stadiometer (Harpenden model 98.603, Holtain LTD, Crosswell, UK) and sitting height table (Harpenden, Holtain LTD, Crosswell, UK) were respectively used to measure height and sitting height to the nearest 0.1 cm. Weight was measured using an electronic scale (Seca model 770, Hanover, MD, USA) to the nearest 0.1 kg. Leg length was calculated by subtracting sitting height to height.

Estimated thigh Volume

The protocol was originally presented for total lower limb volume (Jones & Pearson, 1969) and recently validated for late adolescent rugby players (Carvalho et al., 2012) and circumpubertal boys and girls (Coelho-e-Silva et al., 2013), using dual-energy X-ray absorptiometry (DXA) as reference. Thigh volume of the dominant leg was estimated using several measures, as follows: circumferences at the gluteal furrow (highest possible horizontal circumference), middle thigh (largest possible mid-thigh circumference), distal thigh (minimum circumference above the knee), and lengths between each circumference level.

Adiposity

Skinfolds (triceps, subscapular, suprailiac, anterior and posterior mid-thigh and medial calf) were measured to the nearest millimeter using a Lange skinfold caliper (Beta Technology, Ann Arbor, MI, USA). Skinfolds were summed to provide an estimate of subcutaneous adiposity.

Quality control

A sample 32 players was measured and tested within 1 week for **studies 1** and **2** (**Chapter III**). Intra-observer technical error of measurement were published elsewhere (Figueiredo, Coelho e Silva, & Malina, 2011; Figueiredo, Gonçalves, Coelho e Silva, & Malina, 2009), as follows: height, 0.27 cm; sitting height, 0.31 cm; weight, 0.47 kg; skinfolds, 0.52 to 0.72 mm. Quality control for anthropometric characteristics in studies 3 and 4 (**Chapter IV**) was based on replicate measures assessed in an independent sample of 13 male students aged 20.8±2.1 years. Technical error of measurement (TEM) and percentage of the coefficient of variation (%CV) were 0.37 cm for stature (%CV = 0.21), 0.56 kg for body mass (%CV = 0.81%) and 0.71 cm for sitting height (%CV = 0.76%). Similarly, TEM was 0.64 cm for proximal thigh circumference (%CV = 1.16), 0.78 cm for mid-thigh circumference (%CV = 1.53), and 1.04 cm for distal circumference (%CV = 2.82). Corresponding parameters for front and posterior thigh skinfolds were respectively 1.39 mm (%CV = 11.90) and 1.27 mm (%CV = 13.43). The magnitude of errors was well within the range of several health surveys in the USA and a variety of field surveys, including studies of young athletes (R. M. Malina, 1995).

2.3. Estimated body composition

Estimated fat and free-mass

Body fat percentage was derived from triceps and subscapular skinfold thicknesses and estimated according to (Slaughter et al., 1988). Fat and fat-free components were then derived in kg (**study 1** and **2**).

Air displacement pletismography

The Bod Pod® Body Composition System (Life Measurement Instruments, Concord, CA) was used to evaluate body composition in **study 3** and **4**. This device is based in the principle of whole body densitometry to estimate the amount of fat and fat-free mass. Briefly, it measures weight by an electronic scale and volume by air displacement pletismography. In our studies, residual thoracic volume was estimated as proposed by the manufacturer and total body density (mass per unit volume) calculated by the operating procedures (Dempster & Aitkens, 1995). Lastly, total body density was converted to percent fat using the age specific equations assumed by the software (usually Lohman, except when participants had more than 18 years old and Siri equation was assumed).

2.4. Biological maturation

Biological maturation in youth soccer players is often discussed in the context of skeletal, sexual or somatic maturity. Among the more commonly used indicators are skeletal age (SA) and secondary sex characteristics (pubic hair, genitals and testicular volume). These indicators are often labelled as invasive, being therefore of limited use. Other non-invasive indicators of maturity status involved maturity offset (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002) and predicted age at peak height velocity (APHV). While predicted maturity offset/time before age at PHV provides an estimate of timing, percentage of predicted adult height attained at the time of observation provides an estimate of status (R. M. Malina, Rogol, Cumming, Coelho e Silva, & Figueiredo, 2015).

The prediction of APHV uses current age, height, sitting height, estimated leg length (height minus sitting height), weight and interaction terms to predict maturity offset (time before or after APHV). Validation of the anthropometric equation for predicting APHV was recently attempted in 193 Polish boys followed longitudinally (R. M. Malina & Koziel, 2014). APHV has applicability among average maturing boys 12–16 years in contrast to late and early maturing boys. Differences between predicted and actual APHV were especially apparent at 8–11 and 16–18 years of age. Besides, and although invasive and non-invasive maturity indicators were interrelated, there was relatively poor agreement between maturity classifications based on SA-CA and those based on percentage of predicted mature height and APHV (R. M. Malina, Coelho, Figueiredo, Carling, & Beunen, 2012). Nevertheless, the use of non-invasive maturity indicators raises a great interest and practical use in youth sport.

Identifying early, average and late maturers based on APHV can help on designing appropriate training and competition programs in relation to optimal trainability and readiness. Estimated peak gains in speed, power, strength, and muscular and aerobic endurance occurred, on average, at APHV (i.e., around 13.8 years) in male soccer players, but estimated gains maintained a plateau after APHV for several capacities (Philippaerts et al., 2006), thus providing a window of opportunity for an individuals' development. Nevertheless, the relationship between leg length, sitting height and growth might not be so linear among highly specialized samples of athletes, such as goalkeepers.

Somatic maturity

Chronological age, height, and weight of each boy and midparent height were used to predict mature (adult) height in **studies 1**, **2** and **4**, using the Khamis-Roche protocol (Khamis & Roche, 1994). The rationale for the method is as follows: two youth of the same age can have the same height, but one is closer to mature height than the other. The youngster who is closer to mature height is advanced in maturity status compared with the one who is further from mature height (Robert M. Malina, Bouchard, & Bar-Or, 2004). Parent heights were extracted from national citizen cards which included height measured to the nearest centimetre. According to the authors of the Khamis-Roche method, the median error bound (median absolute deviation) between actual and predicted mature height (PMH) at age of 18 years is 2.2 cm in a sample composed by 223 white American males, also enrolled in the Fels Longitudinal Study. Percentage of predicted mature height (PMH) attained at a given age was positively related with skeletal and sexual maturation in boys (Bielicki, Koniarek, & Malina, 1984), and with youth American football and soccer players (R. M. Malina et al., 2012).

2.5. Training-related variables

Only quantitative measures were considered regarding the training characterization of all participants and were obtained by interview. Accumulated years of soccer training (i.e., training experience), was recorded in all the five studies. Whenever it was possible, training experience was confirmed through the publically available Portuguese Soccer Federation records. Years of current or previous formal experience in sport resulted from an interview with all participants in **study 3**.

The number of hours per week devoted to soccer over the corresponding season of the assessment (training volume) was also included in **study 1**, **4** and **5**. In **study 2** the number of sessions; minutes / hours per session for each goalkeeper was daily recorded by the respective coaches and clubs using standard reporting forms. Although it has not been included in the present report, goalkeeper experience and estimated goalkeeper-training volume were also obtained in 26 young soccer goalkeepers, corresponding to the reliability sample.

2.6. Physiological capacities

All field data in **Chapter 1** were collected under standard conditions in an indoor facility at the University of Coimbra. Coefficients of reliability for replicate tests of 32 players within 1 week were as follows: aerobic performance (0.88), repeated-sprint ability (0.91), change of direction (0.84) and counter-movement jump (0.87) (Figueiredo et al., 2011). The coefficients indicated moderate to high reliabilities.

All field protocols administrated in **Chapter 5** were performed on artificial grass with the players equipped with appropriate goalkeeper wear and soccer boots. The reproducibility of the proposed test is evaluated and discussed in **study 5**.

Field testing

Aerobic performance

Aerobic performance was measured using the 20-m multi-stage continuous shuttle endurance test (Léger L.A., 1988). This standard field test is included in the European fitness test battery (Adam, Council of, Committee for the Development of, & Committee of Experts on Sports, 1988) and in the Portuguese physical education curriculum, so players were presumably familiarized with this protocol. Briefly, 5–10 athletes performed a series of runs across a 20 m track, changing direction at the end of each run to match with an audio signal that was getting progressively faster. Subjects started running at a speed of 8.5 $km \cdot h^{-1}$, and speed increased at various stages (0.5 $km \cdot h^{-1}$ every minute). Each stage was made up of several shuttle runs, and players were instructed to keep pace with the signals as long as possible. The results were recorded as laps taken to complete the 20 m shuttle-run test. Aerobic performance was expressed as the number of completed laps achieved in the shuttle run test.

Repeated-sprint ability

The ability to repeat sprinting efforts with brief periods (RSA) was assessed with the 7 sprints protocol (Bangsbo, 1994). The test included seven consecutive sprints (about 35 m with a slalom) with a recovery period of 25 seconds between sprints during which the player ran/walked from the end line back to the starting line. Photocells were positioned 0.8 m above the floor, which typically corresponded to the hip level. The first pair was positioned along the starting line and the second pair along the finish line. The time for each sprint was recorded by a digital chronometer connected to photoelectric cells (Globus Ergo Timer Timing System, Codogné, Italy). The RSA performance was expressed as the sum of 7 sprints.

Change of direction

The 10 x 5 m shuttle-run test was used to evaluate players' ability of changing direction. Players started from a standing position with the feet on the starting line. On the command "Go", subjects ran 10 consecutive shuttle sprints of 5 m (total 50 m). Both feet had to fully cross the line at each end of the shuttle course. The time to complete the 10 shuttles was recorded with a digital chronometer connected to photoelectric cells placed on the start/finish line (Globus Ergo Timer Timing System, Codogné, Italy). Two trials were performed and the faster of the two was retained for analysis.

Acceleration

Acceleration was evaluated in **study 5**, using two sprint tests, involving straight sprinting of 5 m and 10 m as fast as possible from a standing start position. Time was recorded using a system of dual infrared reflex photoelectric cells (Polifemo; Microgate, Udine, Italy). Players began from a standing start, with the front foot 0.5 m from the first timing gate and accelerated until they've completed the straight sprint. The better of two trials was retained for analysis.

Vertical jump

The vertical counter movement jump (CMJ), using the ergo-jump (Globus, Glo1.etest, Italy) protocol (Bosco, 1994), was administrated in **study 1** to assess legs explosive power. The subjects' position on the platform was the same for the take-off and landing. Participants were instructed to keep their hands on hips from the starting position through counter movement phase, jump and end of the flight trajectory. Prior to jumping, subjects were in a standing position and counter-moved until the knee was flexed approximately to 90°.

A second vertical jump test was also included in **study 5**: the free counter movement, a jump during which the players freely swing their arms (CMJ-free arms). The vertical jump performances in **study 5** were evaluated by means of an optical acquisition system (Optojump; Microgate, Udine, Italy), developed to measure with 10^{-3}-second precision all flying and ground contact times. The Optojump photocells are placed at 6 mm from the ground and are triggered by the feet of the subject at the instant of take-off and are stopped at the instant of contact on landing. Then calculations of the height of the jump were made (Komi & Bosco, 1978). The better of two trials in each test was retained for analysis.

Horizontal jump

Although it has not been included in **study 5**, 26 goalkeepers (reliability sample) were also assessed for horizontal jump. The 5-Jump Test (5JT) was performed on artificial grass, consisting in 5 consecutive strides with joined feet position at the start and end of the jumps. All goalkeepers wore appropriate gear and soccer boots. From the starting joined feet position, the participant was not allowed to perform any back step with any foot; rather, he had to directly jump to the front with a leg of his choice. After the first 4 strides, i.e., alternating left and right feet for 2 times each, he had to perform the last stride and end the test again with joined feet. If the player fell back on completion of the last stride, the test was performed again. 5JT performance was measured with a tape measure from the front edge of the player's feet at the starting position to the rear edge of the feet at the final position. The person assessing the landing had to focus on the last stride of the player in order to exactly determine the last foot print on the grass, as the players could not always stay on their feet on landing. The starting position was set on a fixed point. Goalkeepers had two trials and the better one was recorded.

Laboratorial testing

Isokinetic dynamometry

Isokinetic concentric knee extension and flexion of the dominant leg were measured using a calibrated dynamometer (Biodex System 3, Shirley, NY, USA) at angular velocities of $60^{o}\cdot s^{-1}$ (~ 1.05 $rad\cdot s^{-1}$) and $180^{o}\cdot s^{-1}$ (~ 3.14 $rad\cdot s^{-1}$). Each participant was asked to sit on the dynamometer seat with his back reclined at 85º and a standard stabilization strapping was placed across the trunk, waist, and distal femur. Participants were also instructed to maintain their hands crossed on their shoulders while testing. In the concentric action, participants were encouraged to continuously push the arm lever during extension and pull during flexion as hard and fast as possible. Each participant performed five continuous maximal repetitions at each angular velocity. Visual feedback of moment versus time was provided during the test, but no verbal feedback was given (Baltzopoulos, Williams, & Brodie, 1991).

Raw data was exported and analysed with Windows-based software (Acqknowledge, Biopac Systems Inc., v. 4.1, Santa Barbara, CA, USA). Maximal knee extension and flexion peak torque were expressed in N·m and conventional isokinetic strength ratio (knee flexion peak torque/knee extension peak torque) calculated at $60^{o}\cdot s^{-1}$ and $180^{o}\cdot s^{-1}$. Essentially, a ratio is based on the assumption that the slope of the relationship between logarithmically-transformed numerator and denominator is a value of one (Atkinson & Batterham, 2012), but the use of conventional ratios does not always relate to functional movements during sporting activities. If this is not so, then the ratio will scale inaccurately at the lower and higher ends of the range of measured values, leading to errors in interpreting measurements on individuals and in samples. Still, a normal ratio knee flexors to knee extensors (KF_{cc}/KE_{cc}) of >0.6 is frequently used as an injury prevention and rehabilitation tool (Baltzopoulos & Brodie, 1989).

Cycle-ergometer

Cycling all-out efforts were performed on a friction-loaded cycle ergometer (Monark 894E Peak Bike, Monark AB, Vargerg, Sweden) interfaced with a microcomputer and calibrated for pedal speed and applied resistance. Cycle-ergometer tests began with minimal resistance (basket supported) at 60 rev · min^{-1}. At the researcher signal "3-2-1, go" subjects started to pedal as fast as possible while the resistance was abruptly applied and the computer activated simultaneously. Peak outputs were obtained using a sample rate of 50 Hz. Intraclass coefficient (0.951), TEM (59.3 Hz), and %CV (5.52) indicated that force-velocity measures provided at a precision of 50 Hz were reasonably reliable in trained adults (Duarte et al., 2014).

The Wingate anaerobic test (WAnT) involved pedaling on a cycle ergometer against a constant braking force set as 0.075 kg·kg^{-1} of body mass. Measurements included peak output (highest mechanical power generated using a sampling rate of 50 Hz expressed in watts), mean output (average mechanical power for the 30 s period, watts), explosive power (watt·s^{-1}) given by the ratio obtained from peak power and time of when the peak power is reached (Popadic Gacesa, Barak, & Grujic, 2009), and pedal velocity (rpm). The WAnT has shown to be highly valid and reliable with test-retest coefficients ranging between 0.89 and 0.97 (Bar-Or, 1987).

The Force-velocity test (FVT) involved a set of 3-5 maximal bouts of 10 s trials against a range of braking forces (initial braking force [Fb] set at 0.075 kg·kg^{-1} with subsequent Fb above and below this intensity – randomly). Five minutes of active recovery (60 rev.min^{-1}, unloaded) were allowed between each trial. The output variables in the FVT were estimated using a polynomial equation that is based on the interpolation of peak outputs and Fb: optimal peak output (watts), explosive power (watt·s^{-1}) and pedal velocity (rpm). Given the promising use of the FVT as a measure of short-term power output, it's somewhat surprising that the reliability of the FVT has not been extensively documented according to the used protocols. With this in mind, reproducibility of estimated peak output and pedal velocity derived from multiple 10 s all-out sprints will be evaluated and discussed in **study 3**.

2.7. Soccer-specific skills

In **Chapter 1** soccer-specific skills assume a central role in the characterization of young soccer goalkeepers from the Coimbra Youth Soccer Project (CYSP). In its original purpose, the CYSP was mixed-longitudinal study of growth, maturation, function and performance in male youth players. In other portions of the project these characteristics were examined according to playing position (Coelho e Silva et al., 2010; Valente-Dos-Santos et al., 2014). Trough time, it was found of interest to promote and improve our understanding of the performance characteristics in goalkeepers, since literature regarding position-related rarely included goalkeepers. Thus, this emergent interest on goalkeepers throughout the CYSP and filiation to its early methodological issues resulted in the administration of four convenience tests in **study 1**: ball control with the body, dribbling speed, shooting accuracy (Futebol, 1986) and wall pass (Kirkendall, Gruber, & Johnson, 1987). **Study 2** focused only on longitudinal changes in dribbling speed and passing skills.

The test battery used in the CYSP was selected on the basis of principal component analysis of eight tests administrated to 39 youth players, six from the Portuguese Soccer Federation (Futebol, 1986) – ball control with the body, ball control with the head, dribbling speed, dribbling with a pass, passing accuracy and shooting accuracy, and two from Kirkendall et al. (1987) – wall pass and slalom dribble (Coelho e Silva, Figueiredo, & Malina, 2004). Coefficients of reliability based on replicate tests in a sample of 32 players (Figueiredo et al., 2009) indicated moderate to high reliabilities, as follows: ball control (0.77), dribbling speed (0.74), shooting accuracy (0.71) and passing (0.83). Validity coefficients between performances on a slalom dribble, wall volley and judges' ratings of soccer playing ability ranged from 0.53 to 0.94 (Kirkendall et al., 1987). The test battery was included in previous research with Portuguese youth players of different maturity status and skill levels (R. M. Malina et al., 2005; R. M. Malina, Ribeiro, Aroso, & Cumming, 2007).

Ball control

Also known as juggling, ball control was tested within a 9 x 9 m square, as proposed by the Portuguese Soccer Federation (Futebol, 1986). During this test, players were instructed to keep the ball in the air without using the arms or hands. Score was given by the number of hits of the ball before it felt on the floor. Counting was stopped when the ball hit the floor, the subject stepped of the square or when subject touched the ball with arms or hands.

Dribbling speed

Beginning at one corner of a 9 x 9 m square marked by one cone at each corner, players were required to conduct the ball with the feet (dribble) around the three cones (corner directly opposite to the starting cone, the cone placed midway in the near end). The overall slalom distance was about 40 m. The objective was to complete the drill in the fastest possible time, without knocking the cones. The time for each trial was recorded by a digital chronometer connected with photoelectric cells (Globus Ergo Timer Timing System, Codogné, Italy). The first pair was positioned along the starting line and the second pair along the finish line.

Shooting accuracy

Shooting accuracy was measured as proposed by the Portuguese Soccer Federation (Futebol, 1986). Players had five attempts consisting in kicking the ball at a 2 x 3 m goal located at the line of a 9 x 9 m square. The target was divided into six sections. One rope was placed horizontally between the posts at a height of 1.5 m. Two ropes were dropped from the crossbar, 0.5m from each post. Five points were allocated for the upper right and left sections, and two for the upper middle section. Three points were allocated for the lower right and left sections, and one for the lower middle section. Kicks were attempted with the player standing outside of the square at the line opposite the goal. The maximum score was 25 points. Each attempt was recorded and the test score was subsequently registered.

Passing

Passing skill was measured by the wall pass (Kirkendall et al., 1987). This protocol involved a 1.22 m high (starting from the floor) and a 2.44 m wide target drawn on a flat wall. Players had to remain inside an area of 1.83 m in length and 4.23 m in width marked on the floor, at a 1.83 m distance from the wall. The test consisted of making as many passes to the wall in 20 s. Players were allowed to use all body parts to make a pass against the wall, with the exception of the arms and hands. If the players left the marked area to retrieve a ball or played the ball with the hand, one point was subtracted from the score. The better of two trials was retained for analysis.

2.8. Goalkeeper-specific testing

Study 5 aimed to develop and evaluate two soccer-specific tests designed to assess goalkeeper-specific technique. The final version of the applied tests resulted from an original straight sprint and diving protocol. Later, a change of direction previous to the diving action was added, before which the goalkeeper was asked to accelerate and decelerate until a full stop. Only then the final versions of the proposed tests have emerged to assess goalkeeper-specific diving technique. All these adaptations occurred during three experimental sessions with an independent sample of six goalkeepers.

Sprint-Keeper Test

The Sprint-Keeper Test (S-Keeper) consists in: a) accelerating from a static standing position; b) straight sprint of 3 m; c) turn the cone while performing a change of direction; d) and performing a diving save action on the stationary ball, in a total distance of approximately 10 m. The subject who failed to catch the ball with both hands had to repeat the test. Two electronic timing gates (Polifemo; Microgate, Udine, Italy) were set up with the first gate at the goal line (0 m), and the second gate 7 m to the side at a 45º angle to the marked cone, placed 3 m in front of the starting point. The first pair of the electronic timing system sensors mounted on tripods was set approximately 75 cm above the floor and positioned 4 m apart, while the last pair was set approximately 10 cm above the floor. The ball centre was placed at a distance of 11 cm from the beam and at 8 m from the end line. S-Keeper performance was assessed for both sides and two trials were completed for each side. The best of each trial was retained for analysis.

Lateral Shuffle-Keeper Test (LS-Keeper)

The Lateral Shuffle-Keeper Test (LS-Keeper) consists in: a) accelerating from a standing position; b) straight sprint to cone A (placed 3 m in front of the starting point); c) facing forward and without crossing feet, lateral shuffle to cone B (2 m) and then back to cone A, always giving the inside to cones; d) and performing a diving save action on the stationary ball, in a total distance of approximately 11 m. The subject who crossed one foot in front of the other or failed to catch the ball with both hands had to repeat the test. Two electronic timing gates (Polifemo; Microgate, Udine, Italy) were set up with the first gate at the goal line (0 m) and the second moving 2 m to the side from cone A (placed 3 m in front of the starting point) and 5 m to the front. The first pair of the electronic timing system sensors mounted on tripods was set on the starting line approximately 75 cm above the floor and positioned 4 m apart, while the second pair was set approximately 10 cm above the floor. The ball centre was placed at a distance of 11 cm from the beam and at 8 m from the end line. LS-Keeper performance was assessed for both sides and two trials were completed for each side. The best of each trial was retained for analysis

2.9. Goal orientation

A Portuguese version (Fonseca & Biddle, 1996) of the Task and Ego Orientation in Sport Questionnaire (TEOSQ) (Duda, 1989) was completed by all participants in **study 1**. The TEOSQ includes 13 items which are rated on a five-point Likert scale ranging from strongly disagree (1), disagree, neutral, agree and strongly agree (5). Seven items reflect a task orientation, while six reflect an ego orientation.

A combination of four variables successfully discriminated the elite and sub-elite young players (Reilly, Williams, Nevill, & Franks, 2000). The predictive model of stepwise discriminant analysis included motivational orientation and perceptual skills as psychological variables, whereas anxiety intensity and direction weren't among the most discriminating factors between the two groups of players. In more detail, a positive coefficient for ego orientation (0.66) and a negative coefficient for anticipation 1 *vs* 1 (-0.53) were predicted. For this reason, TEOSQ was selected to assess the psychological construct.

2.10. Statistical analysis

In accordance with the aims of each study, different statistical analyses were performed and are summarized in Table 2.2.

Statistical significance is the probability that the observed difference between two groups is due to chance. If the *p* value is larger than the alpha level chosen (e.g., 0.05), any observed difference is assumed to be explained by sampling variability. A statistical test with large samples will almost always demonstrate a significant difference, even if there are very small differences, unless there is no effect whatsoever. However, these differences can be meaningless. While a *p* value can inform the reader whether an effect exists, the *p* value will not reveal the size of the effect (Sullivan & Feinn, 2012).

In statistics, an effect size is a measure of the strength of a phenomenon. An effect size calculated from data is a descriptive statistic that conveys the estimated magnitude of a relationship without making any statement about whether the apparent relationship in the data reflects a true relationship in the population. For this reason, and depending upon the type of comparisons under study, effect size is estimated with different indices. The indices fall into two main study categories, those looking at effect sizes between groups and those looking at measures of association between variables (Sullivan & Feinn, 2012).

For two independent groups, effect size can be measured by the standardized difference between two means, or mean (group 1) – mean (group 2) / standard deviation. Therefore, the effect size correlations (ES-r) between independent and each dependent variable were estimated and coefficient estimated according to the following thresholds: trivial ($r < 0.1$), small ($0.1 < r < 0.3$), moderate ($0.3 < r < 0.5$), large ($0.5 < r < 0.7$), very large ($0.7 < r < 0.9$), nearly perfect ($r > 0.9$) and perfect ($r = 1$)(Rosnow & Rosenthal, 1996). *Cohen's d*represents the standardized difference, and it can be used to calculate the magnitude of the differences. Interpretation follows the thresholds of 0.20, 0.60, 1.20, 2.00 and 4.00 for trivial, small, moderate, large, very large and extremely large (Hopkins, Marshall, Batterham, & Hanin, 2009).

Based on *Cohen's d* effect size, the smallest worthwhile difference can be determined. It represents the magnitude of improvement in a variable as a function of the between-subject standard deviation. Magnitude-based inferences about effects were qualitatively determined by the following thresholds: <0.5%: most unlikely; 0.5–5%: very unlikely; 5–25%: unlikely; 25–75%: possibly; 75–95%: likely, 95–99.5%: very likely; >99.5%: most likely (Hopkins et al., 2009).

All statistical analyses were carried out using the IBM Statistical Package for the Social Sciences for Windows (SPSS v.22.0, IBM Corp.; Armonk, NY, USA), the GraphPad Prism version 5.03 software (GraphPad Software, Inc.; La Jolla, CA, USA), and the MLwiN version 2.02 software (Centre for Multilevel Modelling; University of Bristol, United Knigdom). Alpha level was set at 0.05.

Table 2.2. Statistical analyses by each study.

Analyses	Study				
	1	2	3	4	5
Descriptive statistics	●	●	●	●	●
z-scores	●				
Kolmogorov-Smirnov test				●	
Shapiro-Wilk test			●		
Effect size correlations	●		●	●	●
Pearson's correlation			●		●
TEM			●		●
Reliability coefficients			●		●
Coefficients of variation			●		●
ICC			●		●
Bland-Altman plot			●		●
Bivariate coefficients of correlation			●		●
Paired samples T-test			●		●
Independent samples T-test				●	
Factorial ANOVA	●				
ANCOVA					●
Stepwise discriminant analysis	●			●	
SWD					●
Additive polynomial multilevel modelling		●			

ANOVA, univariate analysis of variance; TEM, technical error of measurement; ICC, intraclass correlation coefficients; ANCOVA, univariate analysis of covariance; SWD, smallest worthwhile difference.

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Chapter 3

Profiling the Young Soccer Goalkeeper

3.1. Study 1

A

Anthropometric and Physiological Profiling of Youth Soccer Goalkeepers

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3.1.1. Abstract

Studies focusing on position-related characteristics of young soccer players often ignored the goalkeepers. The aim of this study was to examine the effect of playing position on anthropometry, physiological attributes, soccer skills, and goal orientation across adolescence. One hundred forty-five soccer players age 11–19 y were assessed in training experience, body size, maturation, physiological parameters, soccer skills, and goal orientation. Factorial ANOVA was used to test the effect of age group, playing position, and respective interaction terms, while analysis of variance was used to compare goalkeepers vs outfielders in middle (under 13 [U-13] and U-15) and late (U-17 and U-19) adolescence. Discriminant analysis was used to identify the variables that contributed to explaining playing positions. Age group was a consistent source of variation for all variables except task and ego orientations. Fat mass, agility, endurance, dribbling speed, shooting accuracy, and passing were affected by the gradient derived from the classification between goalkeepers and outfielders. It was possible to correctly classify the playing position based on fat-free mass and 3 manipulative skills in younger players and on 4 skills in U-17 and U-19 soccer players. Future research should include longitudinal information to improve our understanding of the factors that contribute to distinguish goalkeepers from outfielders.

Key words: *sport specialization, playing position, growth, skills*

3.1.2. Introduction

Data on young soccer players suggest a maturity-associated variation in body size, composition, and physiological performance[1]as chronological age and sport specialization increase. Across different age groups, particularly in under-13 (U-13) to U-16 categories, players advanced in maturation tend to be taller and heavier.[2–4] They also tend to attain better scores in explosive performance assessed by vertical and horizontal jumping protocols, sprinting, agility, and endurance performance than late-maturing players. Conversely, players of contrasting maturity status do not consistently differ in nonspecific motor-coordination tests[5,6] or in soccer-specific skills (eg, ball control, dribbling, passing, and shooting).[2,7,8]

Literature seems to support the hypothesis that particular anthropometric and physiological characteristics are required by different playing positions both at youth[9–11] and professional levels,[12,13] even considering the different playing roles in each position (eg, central or external defender). Goalkeepers and defenders tend to be taller and heavier,[9,10] as opposed to midfielders and forwards, who tend to be shorter and leaner.[11] Advanced-maturity players are often selected to certain outfield positions as they are larger in body size, faster in short-term protocols, and stronger. Considering the soccer-skills results, the contribution of biological maturity status was small[7] and playing-position variation negligible.[14] However, position-related variation rarely includes goalkeepers, and literature profiling the soccer goalkeeper across stages of long-term sport preparation is still lacking.

Studies that have examined goalkeepers provided relevant information on the anthropometric characteristics and physiological performance,[15] movement patterns and intensity levels.[16,17] Goalkeepers have been classified as heavier and taller and presented higher values of estimated fat mass than same age outfielders.[9,11] No differences were noted in physiological performance except for aerobic protocols such as the Astrand test[9] and the 20-m progressive run test,[10] where goalkeepers obtained the lowest performances. Studies that examined the importance of soccer skills rarely included the goalkeepers, who compared with outfielders, typically demonstrated poorer performances in skill tests such as the Hoff dribbling protocol.[11] Assessing and choosing goalkeepers according to body size, physiological profile, and technical ability places several constraints on coaches and trainers, since the discriminating factors may vary with adolescence. In addition, a different level of specific skill aptitude may be a consequence of an early specialization in goalkeeping and specific training programs.

Nonetheless, profiling goalkeepers and outfielders taking into account growth, biological maturation, physiological parameters, and soccer-specific skills across adolescent years provides relevant information to support long-term preparation regarding selection, promotion, and specialization. Therefore, the current study aimed to examine position-related variation in body size, proportions, maturation, physiological parameters, soccer-specific skills, and goal orientation in young soccer players at different ages. We hypothesized that goalkeepers and outfielders would differ in terms of morphology and physiology but also in manipulative-skill level. Although corresponding data across adolescence are less extensive, we also hypothesized that these differences would vary by chronological age groups.

3.1.3. Methods

Subjects

One hundred forty-five male Portuguese soccer players from several clubs in the district of Coimbra age 11.41 to 18.82 years participated. Players were classified as goalkeepers (n = 71) and outfielders (n = 74; defenders n = 27, midfielders n = 28, forwards n = 19). Fifty-two goalkeepers and all outfielders were extracted from the Coimbra Youth Soccer Project. As this mixed longitudinal study evolved, 19 goalkeepers from other clubs were added to the data set. Selection criteria for goalkeepers included the subjects at baseline of all age groups from 5 soccer clubs in Portugal's midlands with a minimum of 2 years of training. The most-represented club, with 44 goalkeepers and 60 outfielders, is considered regional elite, while the other 4 are considered regional subelite. The Portuguese Soccer Federation provides a 2-year age-group organization: infantiles (U-13), initiates (U-15), juveniles (U-17), and juniors (U-19). The study was approved by the Scientific Committee of the University of Coimbra. The Portuguese Soccer Federation, soccer clubs, and parents provided written consent. Players provided permission when they were over 18 years of age. Players were also informed that participation was voluntary and that they could withdraw at any time.

Methodology

The clubs were involved in a 9-month competitive season (September to May). Training volume ranged from 3 to 5 sessions/wk (90–120 min/session). Training experience in the sport (y) was obtained from each player and verified by club records. The Portuguese Soccer Federation provides open access to information regarding the players' training history. All data were collected over a 2-week period under standard conditions in an indoor facility at the University of Coimbra. Chronological age was calculated by subtracting birth date from date of testing.

Anthropometry

A single trained observer measured all participants following standardized procedures. Height was measured to the nearest 0.1 cm with a Harpenden stadiometer (model 98.603, Holtain Ltd, Crosswell, UK), while body mass was measured to the nearest 0.1 kg with a scale (SECA model 770, Hanover, MD, USA). Skinfolds (triceps, subscapular, suprailiac, medial calf) were measured to the nearest millimeter using a Lange skinfold caliper (Beta Technology, Ann Arbor, MI, USA). Body-fat percentage was derived from the anthropometric measures and estimated according to Slaughter et al.[18] Fat and fat-free components were then derived in kilograms.

Biological maturation

A potential indicator of biological maturity is the percentage of mature (adult) height attained at a given point in time. For the estimation of adult height, the predicting variables—height, body mass, and mean parental height—were used following the protocol suggested by Khamis and Roche.[19] The relationships between several indicators of biological maturation were recently examined in youth soccer players (11–12 y, n = 87; 13–14 y, n = 93); the study revealed the percentage of attained mature height to be related to chronological age, skeletal age, stage of pubic hair, and age at peak height velocity.[20] However, limitations are recognized when using percentage of attained mature height to classify youth into contrasting maturity categories, as concordance with the difference between skeletal age and chronological age was considered poor.

Physiological Parameters

As a team sport, soccer has requirements that are considered multidimensional, and distinguishing characteristics of soccer players can be investigated using a comprehensive and generally accepted test battery.[21] Four variables were recorded for each player. These included repeated-sprint ability (RSA), agility, explosive power, and aerobic endurance. RSA was assessed using the 7-sprint protocol proposed by Bangsbo.[22] The time for each sprint (about 30 m including a slalom) was recorded by a digital chronometer connected to photoelectric cells (Globus Ergo Timer Timing System, Codogne, Italy). The RSA test was expressed as the sum of 7 sprints. The 10 × 5-m shuttle was the measure of agility (time was recorded with a digital chronometer connected to photoelectric cells, following the same procedure as for the RSA test). Explosive power of the lower limbs was assessed using the ergo-jump protocol,[23] including the countermovement jump (CMJ). Two trials were administered for each test, and the better trial was retained for analysis. Aerobic endurance was assessed using the protocol suggested by Léger et al.[24] The test requires the subject to continuously perform a series of 20 m shuttle runs following a cadence set by an audio signal. As speed increases, the time between the signals shortens. The purpose of the test was to perform as many shuttles as possible; the score corresponded to the total meters covered until the athlete was no longer able to maintain the required speed.

Soccer-specific skills

Four specific tests were used to assess the players' soccer skills: ball control with the body, dribbling speed, shooting accuracy (as used by the Portuguese Soccer Federation), and wall pass.[25] A detailed description of the tests can be found elsewhere.[8] Intraclass coefficients based on replicate tests in a sample of 32 players indicated moderate to moderately high reliabilities.[2]

Goal Orientation

A Portuguese version[26] of the Task and Ego Orientation in Sport Questionnaire (TEOSQ[27]) was completed by all players. The TEOSQ includes 13 items that are rated on a 5-point Likert scale ranging from *strongly disagree* (1) to *disagree, neutral, agree,* and *strongly agree* (5). Seven items reflect a task orientation, while 6 reflect an ego orientation. Examples of a task focus are "I learn a new skill and it makes me want to practice more" and "I learn something that is fun to do," while examples of an ego focus are "I'm the only one who can perform the play or the skill" and "I can do better than my friends."

Statistical Analysis

Intraobserver technical error of measurement for anthropometric dimensions and reliability coefficients for physiological parameters and soccer-skills tests were previously presented.[2,14] Based on chronological age, participants were grouped as middle adolescents (U-13 and U-15) and late adolescents (U-17 and U-19). Mean and standard deviation were determined by age group and playing position for the overall sample. Individual composite *Z*-score was calculated for physiological parameters and also for soccer skills. Factorial ANOVA was used to test the effect of age group (U-13 and U-15 and U-17 and U-19) and playing position (goalkeeper and outfielder) on chronological age, training experience, anthropometric and physiological variables, soccer-specific skills, and goal orientation. Analysis of variance was used to test differences between goalkeepers and outfielders in middle and late adolescents. The effect-size correlations (ES-*r*) between independent and each dependent variable were estimated[28] and coefficients interpreted as follows: trivial ($r < .1$), small ($.1 < r < .3$), moderate ($.3 < r < .5$), large ($.5 < r < .7$), very large ($.7 < r < .9$), nearly perfect ($r > .9$), and perfect ($r = 1$). Finally, and separately for each age group, discriminant analysis (stepwise mode) was performed to obtain a linear equation to successfully classify players as goalkeepers or outfielders based on a reduced number of variables. Body mass and the composite scores were not included in the discriminant function analysis. For all tests, alpha level was kept below 5%.

3.1.4. Results

Descriptive values by chronological age group and playing positionare summarized in Table 3.1. Age group was a consistent source of variation in young soccer players for all the variables, with the exception of goal orientation (Table 3.2). Conversely, players differed significantly by playing position in training experience (F = 4.276, P = .040, ES-r = .2), body mass (F = 7.641, P = .006, ES-r = .2), fat mass (F = 11.287, P = .001, ES-r = .3), RSA (F = 16.071, P < .001, ES-r = .3), 10 × 5-m agility (F = 15.788, P < .001, ES-r = .3), 20-m shuttle run (F = 19.535, P < .001, ES-r = .3), physiological composite score (F = 18.312, P < .001, ES-r = .3), dribbling speed (F = 14.693, P < .001, ES-r = .3), shooting accuracy (F = 530.821, P < .001, ES-r = .9), and passing (F = 698.939, P < .001, ES-r = .9). The interaction of age group by playing position was only a source of variation for shooting accuracy (F = 4.780, P = .030, ES-r = .2). Table 3.3 shows the results of comparisons between goalkeepers and outfielders in the U-13 and U-15 age group and the U-17 and U-19 age group. Among the youngest group, goalkeepers were, on average, taller (F = 0.758, P = .387, ES-r = .1) and heavier (F = 3.631, P = .061, ES-r = .2) and had higher fat-free mass values (F = 1.190, P = .198, ES-r = .1). Significant differences were found for fat mass (F = 4.352, P = .040, ES-r = .2). Outfielders obtained better scores in 3 physiological parameters (RSA, F = 14.191, P< .001, ES-r = .4; 10 × 5-m agility, F = 12.226, P = .001, ES-r = .4; 20-m shuttle run, F = 21.075, P < .001, ES-r = .5), resulting in a significant difference in the physiological composite score (F = 13.268, P < .001, ES-r = .4). They also had better results in dribbling speed (F = 7.374, P = .008, ES-r = .3) and passing (F = 345.272, P < .001, ES-r = .9). On the contrary, outfielders had significantly lower points in shooting accuracy (F = 260.111, P <.001, ES-r = .9).

Table 3.1. Descriptive Data Means (Mean ± SD) by Age Group and Playing Position for the Total Sample of Young Soccer Players (N = 145).

	Age Group, y		Playing Position	
	U-13 and U15 (*n* = 76)	U-17 and U19 (*n* = 69)	Goalkeeper (*n* = 71)	Outfielder (*n* = 74)
Chronological age (y)	13.84±1.02	16.46±0.75	14.97±1.74	15.20±1.44
Training experience (y)	4.58±1.47	6.62±1.38	5.28±1.73	5.81±1.76
Attained mature stature (%)	92.2±5.0	99.2±1.1	95.3±5.0	95.7±5.2
Height (cm)	161.4±11.1	174.3±5.9	168.0±10.2	167.1±11.9
Body mass (kg)	52.6±12.2	66.9±10.1	61.8±13.7	57.0±12.6
Fat-free mass (kg)	45.3±8.8	56.2±6.9	51.7±10.0	49.4±9.2
Fat mass (kg)	7.3±4.9	10.8±5.0	10.3±5.3	7.7±4.8
Repeated-sprint ability: sum (s)	57.19±3.56	54.08±2.61	56.77±3.79	54.69±2.87
10 x 5-m, agility (s)	19.21±1.34	18.41±0.83	19.20±1.26	18.47±1.00
Countermovement jump (cm)	31.1±5.4	37.5±4.6	33.7±5.6	34.47±6.24
20-m shuttle run (m)	1148±481	1654±547	1200±530	1570±553
Physiological composite score	-1.65±3.22	1.86±2.23	-0.99±3.40	0.98±2.90
Ball control (#)	46±74	152±225	90±189	102±155
Dribbling speed (s)	13.78±1.20	12.67±0.83	13.59±1.22	12.93±1.04
Shooting accuracy (points)	14±6	16±8	21±4	9±3
Passing (points)	16±7	18±7	10±4	23±3
Skills composite score	-0.83±1.56	1.37±1.97	0.07±2.3	0.36±1.88
Task orientation	4.37±0.48	4.31±0.46	4.37±0.51	4.31±0.43
Ego orientation	1.82±0.69	1.76±0.75	1.83±0.80	1.75±0.64

Table 3.2. Factorial Analyses of Variance to Examine Age Group, Playing Position and the Interaction Term as Significant Sources of Intraindividual Variability for the Total Sample of Young Soccer Players (N = 145).

	Effect of Age Group			Effect of Playing Position			Interaction, Age Group × Playing Position		
	F	*p*	ES-*r*	*F*	*P*	ES-*r*	*F*	*P*	ES-*r*
Chronological age (y)	307.978	< 0.001	0.8 (trivial)	1.155	0.284	0.1 (trivial)	1.946	0.165	0.1 (small)
Training experience (y)	74.065	< 0.001	0.6 (large)	4.276	0.040	0.2 (small)	0.081	0.776	0.0 (trivial)
Attained mature stature (%)	127.810	< 0.001	0.7 (very large)	0.220	0.640	0.0 (trivial)	0.273	0.602	0.0 (trivial)
Height (cm)	74.369	< 0.001	0.6 (large)	0.519	0.472	0.1 (small)	0.573	0.450	0.1 (small)
Body mass (kg)	61.225	< 0.001	0.6 (large)	7.641	0.006	0.2 (small)	0.008	0.930	0.0 (trivial)
Fat-free mass (kg)	70.059	< 0.001	0.6 (large)	3.702	0.056	0.2 (small)	0.004	0.948	0.0 (trivial)
Fat mass (kg)	19.371	< 0.001	0.3 (moderate)	11.287	0.001	0.3 (moderate)	0.004	0.950	0.0 (trivial)
Repeated-sprint ability: sum (s)	39.123	< 0.001	0.5 (large)	16.071	< 0.001	0.3 (moderate)	3.053	0.083	0.1 (small)
10 x 5-m, agility (s)	19.919	< 0.001	0.4 (moderate)	15.788	< 0.001	0.3 (moderate)	2.879	0.092	0.1 (small)
Countermovement jump (cm)	57.346	< 0.001	0.5 (large)	0.516	0.474	0.1 (small)	0.063	0.802	0.0 (trivial)
20-m shuttle run (m)	38.850	< 0.001	0.5 (large)	19.535	< 0.001	0.3 (moderate)	1.431	0.234	0.1 (small)
Physiological composite score	63.493	< 0.001	0.6 (large)	18.312	< 0.001	0.3 (moderate)	2.062	0.853	0.1 (small)
Ball control (#)	14.771	< 0.001	0.3 (moderate)	0.137	0.712	0.0 (trivial)	0.030	0.863	0.0 (trivial)
Dribbling speed (s)	43.395	< 0.001	0.5 (large)	14.693	< 0.001	0.3 (moderate)	0.244	0.622	0.0 (trivial)
Shooting accuracy (points)	25.455	< 0.001	0.4 (moderate)	530.821	< 0.001	0.9 (nearly perfect)	4.780	0.030	0.2 (small)
Passing (points)	27.368	< 0.001	0.4 (moderate)	698.939	< 0.001	0.9 (nearly perfect)	0.110	0.741	0.0 (trivial)
Skills composite score	55.805	< 0.001	0.5 (large)	0.606	0.438	0.1 (small)	0.930	0.336	0.1 (small)
Task orientation	0.512	0.475	0.1 (small)	0.678	0.412	0.1 (small)	0.061	0.805	0.0 (trivial)
Ego orientation	0.267	0.606	0.0 (trivial)	0.321	0.572	0.0 (trivial)	0.552	0.459	0.1 (small)

Among late-adolescent soccer players (U-17 and U-19), goalkeepers were heavier (F = 4.251, P = .043, ES-r = .2) and had reached a lower percentage of the attained mature height (F = 5.265, P = .025, ES-r = .3). Differences were also found for 10 × 5-m agility (F = 4.280, P = .042, ES-r = .2), 20-m shuttle run (F = 4.009, P = .049, ES-r = .2), and the physiological composite score (F = 5.712, P = .020, ES-r = .3). Finally, goalkeepers performed better in the shooting test (F = 267.544, P < .001, ES-r = .9), while outfielders had better scores in dribbling speed (F = 8.440, P = .005, ES-r = .3) and passing (F = 361.248, P < .001, ES-r = .9).

Results of the discriminant function analysis (Table 3.4) indicated a function of 4 variables—passing, shooting, fat-free mass, and dribbling speed—that successfully predicted 100% of players by position (goalkeeper vs outfielder) among the middle-adolescent players (Wilks $\text{Lambda}_{4,1,74}$ = 0.077; $\chi^2_{4,71}$ = 211.557, P < .001; eigenvalue = 11.919; r_c = .961). The function accounted for 100% of variance of the intergroup variability. Correlations between predictors and the linear function used to reclassify the players were ordered as follows: passing (–.626), shooting (.543), training years (–.171), RSA (.171), 20-m shuttle run (–.152), fat mass (.128), dribbling speed (.091), 10 × 5-m agility (.060), fat-free mass (.044), ego orientation (–.041), predicted mature height (–.035), ball control (–.027), task orientation (.019), CMJ (–.005), and height (.001). For the players in late adolescence, a linear combination of 4 variables correctly predicted 100% of the players into the original groups (Wilks $\text{Lambda}_{4,1,67}$ = 0.052; $\chi^2_{4,64}$ = 293.595, P < .001; eigenvalue = 18.350; rc = .974). After 4 steps, the final model included passing, shooting, ball control, and dribbling speed. Correlations between discriminating variables and standardized canonical discriminant functions were also ordered: passing (–.542), shooting (.466), ego orientation (.186), CMJ (.180), RSA (.127), dribbling speed (.083), task orientation (–.078), fat-free mass (.060), fat mass (–.049), predicted mature height (–.034), training years (.033), 10 × 5-m agility (–.031), 20-m shuttle run (–.030), height (.018), and ball control (–.003).

Table 3.3. Descriptive data (mean±SD) by Age Group, Results of Comparison Between Groups and Estimated Effect Size Within Playing Position: Goalkeepers and Outfielders.

	U-13 and U-15					U-17 and U-19				
	Goalkeepers (*n* = 38)	Outfielders (*n* = 38)	*F*	*p*	ES-*r*	Goalkeepers (*n* = 33)	Outfielders (*n* = 36)	*F*	*p*	ES-*r*
Chronological age (y)	13.65±1.08	14.02±0.95	2.517	0.117	0.2 (small)	16.49±0.93	16.44±0.54	0,011	0,918	0,0 (trivial)
Training experience (y)	4.37±1.34	4.79±1.58	1.566	0.215	0.1 (small)	6.33±1.51	6.89±1.21	2,851	0,096	0,2 (small)
Attained mature stature (%)	92.2±5.0	92.2±5.0	0.001	0.977	0.0 (trivial)	98.9±1.2	99.5±1.0	5,265	0,025	0,3 (moderate)
Height (cm)	162.5±10.3	160.3±11.9	0.758	0.387	0.1 (small)	174.3±5.5	174.3±6.3	0,001	0,970	0,0 (trivial)
Body mass (kg)	55.2±12.5	50.0±11.4	3.631	0.061	0.2 (small)	69.4±10.8	64.5±9.0	4,251	0,043	0,2 (small)
Fat-free mass (kg)	46.6±8.8	44.0±8.7	1.690	0.198	0.1 (small)	57.5±7.9	55.1±5.6	311,199	< 0.001	0,9 (nearly perfect)
Fat mass (kg)	8.6±5.3	6.0±4.1	4.352	0.04	0.2 (small)	12.2±4.8	9.5±4.9	2,601	0,111	0,2 (small)
Repeated-sprint ability: sum (s)	58.61±3.77	55.77±2.72	14.191	< 0.001	0.4 (moderate)	54.66±2.54	53.54±2.58	3,257	0,076	0,2 (small)
10 x 5-m, agility (s)	19.71±1.30	18.70±1.20	12.226	0.001	0.4 (moderate)	18.62±0.94	18.21±0.67	4,280	0,042	0,2 (small)
Countermovement jump (cm)	30.88±5.28	31.27±5.60	0.099	0.754	0.0 (trivial)	37.0±4.0	37.8±5.0	0,0545	0,463	0,1 (small)
20-m shuttle run (m)	923±456	1373±397	21.075	< 0.001	0.5 (large)	1519±424	1777±620	4,009	0,049	0,2 (small)
Physiological composite score	-2.90±3.26	-0.40±2.69	13.268	< 0.001	0.4 (moderate)	1.21±1.92	2.45±2.35	5,712	0,020	0,3 (small)
Ball control (#)	38±87	53±57	0.782	0.379	0.1 (small)	149±251	154±203	0,010	0,922	0,0 (trivial)
Dribbling speed (s)	14.13±1.21	13.42±1.08	7.374	0.008	0.3 (moderate)	12.96±0.88	12.41±0.69	8,440	0,005	0,3 (moderate)
Shooting accuracy (points)	19±3	8±3	260.111	< 0.001	0.9 (nearly perfect)	23±3	10±3	267,544	< 0.001	0,9 (nearly perfect)
Passing (points)	9±3	22±3	345.272	< 0.001	0.9 (nearly perfect)	12±3	24±2	361,248	< 0.001	0,9 (nearly perfect)
Skills composite score	-1.08±1.72	-0.57±1.36	2.082	0.153	0.2 (small)	1.39±2.09	1.34±1.87	0,013	0,909	0,0 (trivial)
Task orientation	4.39±0.54	4.34±0.42	0.167	0.684	0.0 (trivial)	4.35±0.48	4.27±0.45	0,575	0,451	0,1 (small)
Ego orientation	1.90±0.78	1.74±059	0.993	0.322	0.1 (small)	1.75±0.82	1.77±0.70	0,013	0,908	0,0 (trivial)

Table 3.4. Summary of Stepwise Discriminant Analysis to Predict Playing Position (Goalkeeper versus Outfielder) in the Under-13 (U-13) and U-15 Age Group (n = 76) and in U-17 and the U-19 Age Group (n = 69).

			Wilks' Lambda				F			
Age group	Step	Predictor entered	Statistic	df1	df2	df3	Statistic	df1	df2	*P*
U-13 and U-15	1	Passing	0.176	1	1	74	345.272	1	74	< 0.001
	2	Shooting accuracy	0.090	2	1	74	370.419	2	73	< 0.001
	3	Fat-free mass	0.083	3	1	74	263.734	3	72	< 0.001
	4	Dribbling speed	0.077	4	1	74	211.557	4	71	< 0.001
U-17 and U-19	1	Passing	0.156	1	1	67	361.248	1	67	< 0.001
	2	Shooting accuracy	0.067	2	1	67	457.630	2	66	< 0.001
	3	Ball control	0.055	3	1	67	371.035	3	65	< 0.001
	4	Dribbling speed	0.052	4	1	67	293.595	4	64	< 0.001

3.1.5 Discussion

The present study used a cross-sectional analysis of youth soccer players in order to examine the effect of age and position in body size, proportions, maturity, physiological parameters, soccer-specific skills and goal orientation. Results were generally consistent with the hypothesis that goalkeepers and outfielders differed in all variables except height, fat-free mass, CMJ, ball control, skills composite score and goal orientation. In contrast, discriminating factors remain relatively stable across chronological age groups.

As expected, age was a consistent source of variation in all anthropometric variables—this was expected, as 4 chronological age groups were included in the analysis. The younger group of adolescent soccer players showed a greater intraindividual variability, expressed by attained mature height (Table 3.1), that is, larger variation in the timing of growth. Development in general and specific motor tests relative to the time of maximal growth in height[29] suggests that performance tests are probably related to the adolescent spurt in muscle mass that occurs shortly after peak height velocity. Unlike the results for anthropometric, physiological, and skilled-performance characteristics, both task and ego orientation were not affected by age group, playing position, or the age-group × playing-position interaction. In a smaller chronological age range, Figueiredo et al.[2] showed that 13- to 14-year-old players had significantly lower results than 11- to 12-year-olds for ego orientation. Ego-oriented players usually place greater emphasis on competitive edge, self-esteem, and social status.

A comparison by playing position within each chronological age group revealed a variation between goalkeepers and outfielders in attained mature height and body mass in late adolescents (Table 3.3). Results from the current study also showed that goalkeepers had higher values for fat tissue than outfielders in both age groups (U-13 and U-15, 8.6 ± 5.3 vs 6.0 ± 4.1; U-17 and U-19, 12.2 ± 4.8 vs 9.5 ± 4.9). The same trend has been reported among 11- to 16-year-old soccer players, with goalkeepers being consistently heavier than defenders, midfielders, and forwards[1,9] and showing higher fat-mass values. Evidence suggests that anthropometry correlates with specialization and success in specific playing positions. Participants who are taller and heavier are more suitable to be goalkeepers and central defenders in both youth[10,11,30] and professional levels. It seems that coaches anticipate the potential of players under their instruction and are orienting heavier and taller players to particular positions in advance.

Differences were found across all age groups regarding agility, endurance, and the physiological composite score. Several authors[9,10] have reported that goalkeepers have lower aerobic endurance than defenders, midfielders, and forwards. Gil et al[9] observed similar agility performance when compared with forwards, despite using an agility test over 30 m, which was not suited for goalkeepers. While the movement patterns are mainly characterized by long periods of low intensity,[16] goalkeepers are often required to perform moderate- to high-intensity multidirectional movements and a number of skillful actions during a match. Thus, goalkeeper training sessions are characterized by the repetition of high-intensity technical actions that require good aerobic endurance to ensure full recovery between repetitions. In contrast to the findings from the younger group, RSA did not differ among U-17 and U-19 soccer players, probably reflecting training programs more suitable for the goalkeepers' specific demands and individual trainability. A recent study[30] highlighted the importance of good jumping capacity in elite U-19 goalkeepers. This tendency is more evident at a professional level, where goalkeepers have significantly higher scores in relation to all playing positions.[12,13] However, our results are consistent with data from previous studies with youth soccer players[9–11] showing no significant differences between goalkeepers and outfielders across adolescence. It is possible that goalkeeping training programs do not have sufficient position-specific training in youth soccer. Therefore, we suggest that coaches select training exercises best suited to the activity profile of goalkeepers starting at young ages. Specific tasks might include jumping coordination such as single- or double-leg hop or squat, lateral step-ups, and lunge movements.

The current results showed that playing position was a consistent source of variation for composite physiological scores, with outfielders having better overall estimates of physiological performance. On the other hand, no differences were found for the skills composite score in adolescent soccer players, although differences were found for dribbling speed, shooting accuracy, and passing. Soccer-specific skills assessment rarely included the goalkeepers, since most of the known soccer-skills tests reflect common technical actions among outfielders. Still, a study with 70 U-14 young male soccer players from Hong Kong reported positional differences in the Hoff dribble test, where midfielders dribbled significantly longer distances than goalkeepers.[11] Results of the current study support the previous findings, given that outfielders scored better in the dribbling-speed and passing tests, which suggests the possibility that goalkeepers are chosen due to their lack of skills compared with their peers.

Previous literature stressed the importance of ego orientation to discriminate 31 English soccer players age 15.8 to 16.7 by competitive level.[21] Notably, goalkeepers and outfielders showed divergent trends as they got older. A decrease was noted among goalkeepers (1.90 ± 0.78 vs 1.75 ± 0.82), while outfielders experienced a slight increase (1.74 ± 0.59 vs 1.77 ± 0.70) in this behavioral variable. In addition, the current study failed to show association between playing position and goal orientation.

Age-specific stepwise discriminant function analyses were conducted to predict playing level based on clubs' competitive divisions.[3,14,21] However, no set of variables capable of discriminating young soccer players as goalkeepers or outfielders was identified in literature. In the current study, specific skills had a strong predictive power in adolescent soccer players, while fat-free mass also contributed in the younger group. The possibility of earlier specialization in technical skills is suggested, and there remains a differentiation across middle and late adolescence and professional level. Although the results of the current study suggest that the battery of predictor variables was able to correctly predict 100% of goalkeepers and outfielders based on body composition and manipulative skills, an emphasis should be placed on a long-term approach to determine the player's progress, both physiological and technical (ie, responsiveness to training).[15]

3.1.6. Practical Implications

Although the awareness of effective training programs for goalkeepers is growing among coaches, there is little information available on long-term training programs developing young, talented goalkeepers. The period before middle adolescence highlighted in this study seems to be optimal in the technical specialization of goalkeepers. However, the evolutionary tendency of the game requires goalkeepers to excel in a wide range of physical, technical, and tactical behaviors, particularly in offensive actions such as distribution and ball control. Coaches should consider age-specific methodologies from childhood and early adolescence to provide appropriate technical-tactical contents that will help young athletes enhance their mastery in goalkeeping performance.

3.1.7. Conclusion

Playing-position variation was especially associated with body mass, fat mass, maturity, physiological parameters, and soccer skills characteristic in youth soccer players, with the exception of goal orientation, CMJ, and ball control. Dribbling speed, shooting accuracy, and passing were common variables to predict playing position in young soccer players, while fat-free mass and ball control entered the model in middle and late adolescence, respectively. The linear combination of predictors was able to correctly predict 100% of goalkeepers and outfielders. Future studies should use a longitudinal research design to improve our understanding of the factors that contribute to distinguish goalkeepers from outfielders. It is also important to recognize that to properly characterize performance characteristics of soccer goalkeepers, position-specific test measures should be developed.

3.1.8. Acknowledgements

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3.2. Study 2

Longitudinal Study of Aerobic Performance and Soccer-Specific Skills in Male Goalkeepers Aged 11 – 18 Years

Submitted

3.2.1 Abstract

Playing-position variation has recognized the importance of aerobic performance and soccer-specific skills in young goalkeepers. Thus, we aimed to evaluate the contribution of chronological age, maturation and body size to the longitudinal changes in aerobic performance and soccer-specific skills in youth soccer goalkeepers aged 11 to 18 years. Sixteen goalkeepers were annually followed over a minimum of 3 to 5 years (4.4 measurements per goalkeeper). Anthropometric characteristics, training experience and annual volume training were recorded. All participants were assessed in the 20-m shuttle-run test, the dribbling speed test and the wall pass test. Multilevel modelling was used to predict developmental changes in aerobic performance, dribbling speed and passing across ages. The multilevel models showed that a training enhancement of 1000 h predicts 3 seconds and 5 points of improvement in soccer-specific skills. Further, age was a consistent source of variation in all performance indicators as one year predicts improvements in the performance scores of 192.5 m (279%), 0.35 s (26%) and 1 point (41%), correspondingly. Our results highlighted the importance of training in the development of aerobic performance and soccer-specific skills, and may provide a framework for trainers and coaches to develop and evaluate effective training programs for individual goalkeepers.

Key words: *soccer, development, sport specialization, playing position*

3.2.2. Introduction

The physical and technical demands of soccer goalkeeper's during match-play have considerably changed over the recent years. While the movement patterns are mainly characterized by long periods of low intensity, goalkeepers are usually required to perform moderate-high intensity multi-directional movements and a number of skilful actions (Di Salvo, Benito, Calderon, Di Salvo, & Pigozzi, 2008; Sainz de Baranda P., 2008; Ziv & Lidor, 2011). The activity profile of 62 goalkeepers in the English Premier League was examined over 109 matches (Di Salvo et al., 2008). Overall, the goalkeepers covered an average of 5611±613 m per match, while just 2% of the time involved brief occasions of high-intensity activities. Of the defensive technical actions performed by goalkeepers (23.4 per match) during the 2002 FIFA World Cup in Korea and Japan, the save was used 41.6% of the time, foot control 27.8%, and the clear out 12.6% (Sainz de Baranda P., 2008).

The evolutionary tendency of the game requires the goalkeeper to excel in a wide range of physical, technical and tactical behaviours, particularly in offensive actions. Dribbling speed, shooting accuracy and passing tests were common variables to predict playing position in young soccer players, while fat-free mass and ball control entered the model in middle and late adolescence, respectively (Rebelo-Goncalves, Coelho, Severino, Tessitore, & Figueiredo, 2015). Position-related variation regarding youth soccer goalkeepers tend to classify them as heavier and taller, with higher values of estimated fat mass when compared to outfield players (Gil, Gil, Ruiz, Irazusta, & Irazusta, 2007; Wong, Chamari, Dellal, & Wisloff, 2009).

Generally, no differences were recognized in physiological performance except for aerobic protocols such as the Astrand test (Gil et al., 2007) and the 20-m progressive run test (Lago-Peñas, Casais, Dellal, Rey, & Dominguez, 2011) where goalkeepers obtained the lowest results. Evidence also suggests aerobic performance and ball control skill as discriminant factors between goalkeepers when compared by competitive level (Rebelo et al., 2012). Nevertheless, the dynamic nature of some anthropometric, physiological and skill markers must be considered as these change over time (Mirkov, Kukolj, Ugarkovic, Koprivica, & Jaric, 2010; Philippaerts et al., 2006; Vaeyens et al., 2006). For example, variance in functional composite score was explained in 37% by age, body mass and adiposity among players aged 11–12 years, while 58% of variance was explained by experience, age, skeletal age, adiposity and sitting height ratio in 13–

14 year-old players (Figueiredo, Coelho e Silva, & Malina, 2011). In the same study conducted with 143 Portuguese young players, the predictors explained 26% (age and adiposity) and 18% (age and skeletal age) of the variance in the composite skill score among, respectively for age groups.

Corresponding information on longitudinal changes stressed the importance of age, maturation and fat mass in physiological composite score, while developmental changes in soccer-specific skills appeared to be, in part, explained by age, playing position, fat and fat-free mass, annual volume of training, repeated-sprint ability and aerobic performance (Valente-dos-Santos et al., 2012). Also, applying multilevel models in youth soccer allowed to assess developmental changes in physiological and skill domains by maturity groups (Deprez et al., 2014; Valente-Dos-Santos, Coelho, Vaz, et al., 2014) and playing position (Huijgen, Elferink-Gemser, Post, & Visscher, 2010; Valente-Dos-Santos, Coelho, Duarte, et al., 2014). However, hardly any longitudinal information exists on the developmental nature of particular elements of performance in goalkeeping.

The overall purpose of the current study was to promote an understanding of longitudinal changes in aerobic performance and soccer-specific skills of young male soccer goalkeepers. Therefore, this study aims: 1) to describe the characteristics of young goalkeepers aged 11–18 years considering maturation, body size, aerobic performance, dribbling speed and passing; and 2) to identify and examine the longitudinal predictors of aerobic performance and soccer-specific skills. It was hypothesized that the prediction of longitudinal changes in aerobic performance and soccer-specific skills would require different models. Additionally, different tempo of development was expected for the estimated performance curves.

3.2.3 Methods

Subjects and procedures

The research was approved by the Scientific Committee of the University of Coimbra and by the Portuguese Foundation for Science and Technology [PTDC/DES/121772]. The Portuguese Soccer Federation and clubs were contacted and institutional agreements were signed between the University and sport organizations to assure data collection over five years. Parents/guardians provided informed consent and players provided their assent. All procedures adhered to established ethical standards for human studies (2008).

Sixteen male goalkeepers aged 11–13 years at baseline, from the Coimbra Youth Soccer Project, were annually followed over a minimum period of 3 to 5 years. A total of 71 observations (average 4.4 observations per goalkeeper) were available for the analysis (Table 3.5). Selection criteria included goalkeepers from five soccer clubs in the midlands of Portugal which regularly participated at national level competitions, with a minimum of 2 years of prior soccer-specific training at baseline. The sample was a group from which potentially talented players could be identified. All data were collected within a 2-week period during Easter break, an official school holiday, and were done at the same hours (6:00 to 7:00 PM). Field testing was performed under standard conditions in an indoor facility with a flat non-slip wood surface at the University of Coimbra.

Table 3.5. Number of soccer goalkeepers and number of measurements per age group.

	Number of measurements			
Age	3	4	5	Total
U-13	2	0	8	10
U-15	4	5	17	26
U-17	3	6	17	26
U-19	0	1	8	9
Total measurements	9	12	50	71
Number of goalkeepers	3	3	10	16

Variables

Variables considered in the study were included among the generally accepted components of "soccer talent" (Reilly, Williams, Nevill, & Franks, 2000). Specific details for the measurement and testing protocols have been previously reported (Valente-dos-Santos et al., 2012) but are briefly described.

Training history

Clubs were involved in a 9-month competitive season (September-May) organized by the Portuguese Soccer Federation. Under-13 (U-13; 11-12 years) and Under-15 goalkeepers (U-15; 13-14 years) had ~ 3 training sessions (~ 90 min·session-1) and one game per week. Under-17 (U-17; 15–16 years) and Under-19 goalkeepers (U-19; 17-18 years) participated in 3-5 training sessions (90–120 min·session^{-1}) and one game per week. Years of formal participation in the sport were obtained through the publically available Portuguese Soccer Federation records and confirmed by an interview at clubs. Training participation (number of sessions; minutes / hours per session) for each goalkeeper was daily recorded by the respective coaches and clubs using standard reporting forms. Modification of usual training volume associated with injury, illness and competition were noted and accounted in final calculations.

Age and biological maturation

Chronological age (CA) was calculated as the difference between date of birth and date of testing. CA, stature, and body mass of each subject and midparent stature were used to predict mature (adult) stature using the Khamis–Roche protocol (Khamis & Roche, 1994). The median error bound (median absolute deviation) between actual and predicted mature stature at 18 years of age is 2.2 cm in a sample of 223 white American males (Khamis & Roche, 1994). Current stature expressed as a percentage of predicted mature stature, is positively related to skeletal maturity during adolescence (Malina, Bouchard, & Bar-Or, 2004).

Anthropometric Characteristics

The same trained technician measured stature, body mass, and two skinfold thicknesses (triceps and subscapular) following standard procedures (Lohman, Roche, & Martorell, 1988). Players wore shorts and a t-shirt; shoes were removed. Intra-observer technical errors of measurement for stature (0.27 cm), body mass (0.47 kg), and skinfolds (0.47-0.72 mm) were within the range of several health surveys in the United States and a variety of field surveys, including studies of young athletes (Malina et al., 2004). Percentage of body fat was estimated from age and gender specific anthropometric formulas (Slaughter et al., 1988). Fat mass (FM) and fat-free mass (FFM) were derived.

Aerobic performance

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

Dribbling speed

To assess dribbling speed, a cone was placed on each corner of the 9 x 9 m square, following the recommendations of the Portuguese Soccer Federation was used (1986). A fifth cone was placed midway (4.5 m) on the line where the test started. The overall slalom distance was approximately 40 m. Beginning at one corner, the participant was instructed to move the ball with the feet (i.e., dribble) around the three cones in slalom fashion, and then dribble the ball to the fifth cone. Two trials were administered and the faster of the two was retained for analysis. Based on the ratio of within-subject and inter-subjects variances, reasonable reliability ($R = 0.74$) has been reported for the dribbling speed test (Figueiredo, Goncalves, Coelho-e-Silva, & Malina, 2009). Validity coefficients between performances on a slalom dribble and ratings of soccer playing ability ranged from 0.53 to 0.94 (Kirkendall, Gruber, & Johnson, 1987). A sufficient face validity can be assumed since the test assess specific elements of the sport.

Passing

The wall pass test (Kirkendall et al., 1987) involved a 1.22m high (starting from the floor) and 2.44 m wide target drawn on a flat wall. At a distance of 1.83m from the marked wall, an area of 1.83 m in length and 4.23 m in width was marked on the floor. The goalkeeper had to remain in this area. The test consisted of making as many passes to the wall in 20 s. Goalkeepers could use all body parts except the hands to make a pass to the wall. The best of two trials of each soccer-specific test was retained for analysis.

Statistics

Means and standard deviations were calculated for CA, training history, maturation, body size and composition, and for aerobic performance, dribbling speed and passing ability. Multicollinearity was examined for the three Models of predictors (Model 1: potential predictors of aerobic performance; Model 2: potential predictors of dribbling speed; and, Model 3: potential predictors of passing), using correlation matrix and diagnostic statistics (Schroeder, 1990). Variables with small tolerance (≤ 0.10) and a VIF > 10 (corresponding to an R^2 of 0.90) are generally considered indicative of harmful multicollinearity (Slinker & Glantz, 1985). For the longitudinal analyses, hierarchical (multilevel) random-effects models were constructed using a multilevel modelling approach (MLwiN 2.02). Multilevel modelling effectively captures the feature that the variance of the observations increases with time, and permits individual slopes and intercepts. It thus provides the opportunity to determine the effects of each predictor variable on the slope and intercept and its significance can be determined by relating the observed effects to the respective change in standard errors (Baxter-Jones & Mirwald, 2004). Thus group effects larger than within-individual variation can be identified.

Longitudinal studies often deal with missing data and experience dropout occurrences. In the multilevel model technique, the number of observations and temporal spacing between measurements can vary among subjects. All available data can thus be incorporated into the analysis. It is assumed that the probability of being missing is independent of any of the random variables in the model. As long as a full information estimation procedure is used, such as maximum likelihood in MLwiN for normal data, the actual missing mechanism can be ignored (Rasbash et al., 1999).

Aerobic performance, dribbling speed and passing ability developmental changes were assessed within individuals (level 1 of the hierarchy) and between individuals (level 2 of the hierarchy). Detailed description of multilevel modeling and complete details of this approach are presented elsewhere (Baxter-Jones & Mirwald, 2004). Briefly, additive polynomial (Rasbash et al., 1999) random-effect multilevel regression models were adopted. In a first attempt, the constant and CA were allowed to vary randomly between individuals (level 2). However, CA (our time-dependent variable) dramatically increased the parameter estimate of variance at level 2, around the between-individuals intercept. This is because all individuals have different developmental performance trajectories. To overcome this problem, it was decided to shift the origin of the explanatory random variables (CA) by centering to its mean values (i.e., CA 14.98 years) (Rasbash et al., 1999).

Subsequently, predictor variables were accepted as significant if the estimated mean coefficient was greater than twice the standard error of the estimate ($P<0.05$). If the retention criterion was not met, the predictor variable was discarded. The final models included only variables that were significant independent predictors. To allow the nonlinearity of the aerobic performance, dribbling speed and passing ability development, an age power function (i.e., centered CA^2) was introduced into the linear models. Alpha level was set at 0.05.

3.2.4. Results

Age, training history, percentage of predicted mature stature, anthropometric characteristics, aerobic performance and soccer specific-skills, by age group, are described in Table 3.6. As expected, all scores generally improved with age (lower scores for time elapsed tests correspond to better performances).

Table 3.6. Descriptive statistics (X±SD) for soccer goalkeepers in each competitive age group.

	U-13 (n = 10)	U-15 (n = 28)	U-17 (n = 25)	U-19 (n = 8)
CA (years)	12.15±0.52	14.19±0.60	16.04±0.55	17.95±0.62
Training experience (years)	3.7±0.9	4.6±1.4	6.0±1.5	7.3±1.5
Annual volume training (h)	123.0±27.3	146.0±34.0	172.2±37.6	218.6±42.5
Predicted mature stature (%)	86.0±2.6	94.5±3.6	98.5±1.5	99.4±1.0
Stature (cm)	151.4±5.3	166.4±8.6	173.6±5.3	176.2±6.1
Body mass (kg)	43.0±7.4	59.6±11.1	68.4±9.5	71.9±14.2
Fat-free mass (kg)	37.4±5.0	49.9±7.5	56.4±6.7	58.2±9.9
Fat mass (kg)	5.6±4.4	9.7±5.2	12.0±4.6	13.7±6.2
Aerobic performance (m)	520±244	1077±416	1396±371	1970±241
Dribbling speed (s)	15.50±0.91	13.66±0.91	13.10±0.95	12.30±0.58
Passing (points)	17.4±3.3	19.9±2.9	22.6±3.6	25.3±2.4

Table 3.7 summarizes the results from the multilevel models for the development of aerobic performance, dribbling speed and passing. Age centered (around 15 years) was added as both fixed and random coefficient. The random effect coefficients describe the two levels of variance [within individuals (level 1 of the hierarchy) and between individuals (level 2 of the hierarchy)]. For all three models, the significant variances at level 1 of the models indicate that both aerobic performance and the soccer-specific skills were improving significantly at each measurement occasion (Figure 3.1, panel a-c) within individuals (estimated mean coefficients > 2 × SE; P < 0.05). The between individual variance matrix (level 2) for each model indicated that individuals had significantly different aerobic performance and soccer-specific skills growth curves, both in terms of their intercepts (Constant / Constant; P < 0.05) and the slopes of their lines (Age centered / Age centered; P < 0.05). The variance of this intercepts and slopes was positively and significantly correlated (Constant / Age centered; P < 0.05) for aerobic performance and passing. The variance around the average line was therefore different at different ages. To shape individual curves, and thus make the models non-linear, the power function of age centered (i.e., age centered^2) was added as fixed effects.

Table 3.7. Multilevel regression analysis of aerobic performance, dribbling speed and passing development (n = 71).

Variable	Aerobic performance		Dribbling speed		Passing	
Fixed effects						
Constant	1207.8±75.1		14.8±0.5		16.0±1.7	
Fat-free mass	NS		NS		NS	
Stature	NS		NS		NS	
Age centered	192.5±18.5		- 0.35±0.07		1.07±0.24	
Age centered^2	NS		0.05±0.02		NS	
Predicted mature stature	NS		NS		NS	
Annual volume training	NS		- 0.003±0.001		0.005±0.002	
Random effects						
Level 1						
Constant	4499.4±858.5		0.34±0.06		4.35±0.83	
	Constant	Age Centered	Constant	Age Centered	Constant	Age Centered
Level 2						
Constant	7921.2±3136.0		0.33±0.15		4.85±2.07	
Age Centered	0.22±0.08	0.15±0.06	0.01±0.01	0.03±0.01	0.41±0.09	0.07 ±0.03

Note: Fixed-effect values are estimated mean coefficients±SE; Random-effects values are estimated mean variance±SE (standard error); NS (P>0.05), not significant and variable removed from the final model.

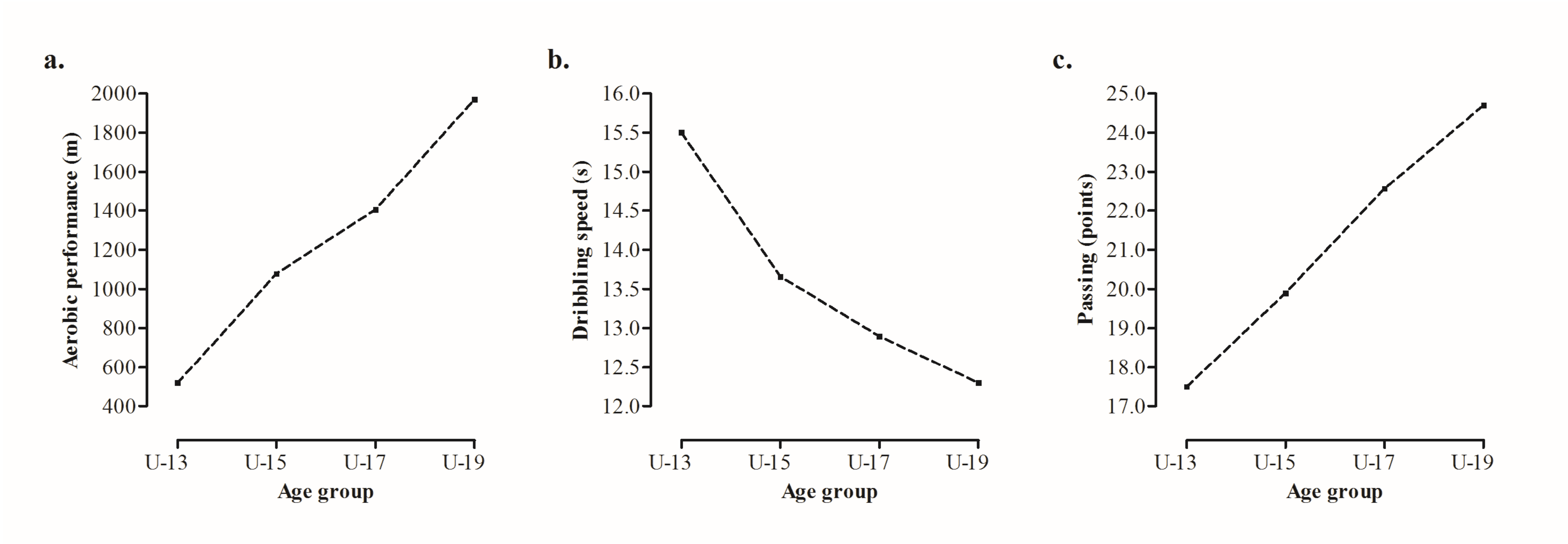

Figure 3.1. Estimated aerobic performance (panel a), dribbling speed (panel b) and passing ability (panel c) aligned by age group. Data are predicted from the multilevel models in Table 3.7.

As seen in Table 3.7, only age significantly predicted the development of aerobic performance ($P < 0.05$). Age centered, age centered^2 and annual volume training significantly contributed to the predication of dribbling speed development ($P < 0.05$). Similarly, age centered and annual volume training were significant predictors of passing development ($P < 0.05$). The Model for goalkeeper's passing ability, for example, indicates that once age is controlled [1 year predicts ~1 point (5%, considering the U-13 group as reference) of improvement in the passing test], a significant independent effect of annual volume training is apparent [1000 h predicts 5 points (29%, considering the U-13 group as reference) of improvement in the passing test].

The estimated curves for aerobic performance, dribbling speed (the developmental curve for dribbling speed is flatter compared to aerobic performance and passing ability, which means that shooting ability is less explained by age) and passing ability were plotted by age group in Figure 3.1 (panel a-c, respectively). Aerobic performance, dribbling speed and passing ability, improved 279%, 26% and 41%, from U-13 group to the U-19 group, respectively.

3.2.5. Discussion

This study investigated the contribution of chronological age, annual volume training, maturation and body size in the development of aerobic performance, dribbling speed and passing ability among male soccer goalkeepers aged 11–18 years. Based on the multilevel models, one year predicts improvements in the performance scores of 192.5 m, 0.35 s and 1 point, correspondingly. Alongside with age and age centered^2, annual volume training was a significant predictor of the development of dribbling speed (1000 h predicts an improvement of 3 s). There also appears to be an independent training effect in passing skill (1000 h predicts 5 points). Further, the estimated performance curves for aerobic performance and soccer-specific skills derived from the respective models suggest that dribbling speed and passing scores are less dependent on this chronological variable as improvements were 279%, 26% and 41%, respectively. Our results highlighted the importance of training in the development soccer-specific skills in male soccer goalkeepers.

Results from the current study also showed a progressive improvement in aerobic performance and soccer-specific skills with age. A similar finding was observed in a cross-sectional sample of Portuguese players (Figueiredo et al., 2011). Consistently, CA was among the predictors of three physiological capacities and three soccer-specific skills and the respective composite scores in male players aged 11–12 years. At the age of 13–14 years the contribution of CA in soccer skills was smaller when compared to physiological performance. In contrast, another study failed to confirm the relative contribution of CA on the composite soccer skill, although the narrow age range sample might explain this result in adolescent soccer players aged 13.2–15.1 years (Malina, Ribeiro, Aroso, & Cumming, 2007). Analysis of age (per se) can limit our understanding of the developmental changes in youth soccer since training experience proportionally follows CA. At the youngest competitive age group (U-13), players in our study have, on average, 3.7 years of soccer training. As goalkeepers reach the U-19 age group, they add up a total 7.3 years of soccer practice. So, cautions are advised when analysing the CA influence over longitudinal changes in multidimensional performance characteristics of young players.

Longitudinal multilevel modelling analyses of soccer-specific aerobic performance comprised predictors related to age, stature, fat mass and backward balance, with negligible effect of maturation (Deprez et al., 2014). In contrast, other studies suggested skeletal maturity status as a significant predictor of physiological capacities (Valente-dos-Santos et al., 2012) and explained inter-individual variability on maximal short-term run performances with and without ball possession at early ages of participation in competitive soccer (Valente-Dos-Santos, Coelho-e-Silva, Vaz, et al., 2014). However, results in this study showed no significant effect of biological maturation. It's possible that the reasonably small sample size (16 goalkeepers in a total of 71 measurements) made it unable to draw more inferences.

Recently, soccer-specific skills were acknowledged as important discriminating factors between goalkeepers and outfield players, particularly for passing and dribbling speed (Rebelo-Goncalves et al., 2015). In line with our results, previous evidence suggested the significant contribution of the amount of training to dribbling performance (Huijgen et al., 2010; Valente-Dos-Santos, Coelho-e-Silva, Duarte, et al., 2014). In this regard, a recent study stressed the importance for better quantification and clarification of training related activities when using the "annual training volume", since this indicator might not be sufficiently sensitive (Valente-Dos-Santos, Coelho-e-Silva, Duarte, et al., 2014). Among 267 talented Dutch soccer players aged 12–19 age (Huijgen et al., 2010), the development of dribbling performance showed the most rapid improvements from ages 12 to 14, continuing to improve further after the age of 16. During the period of 14 to 16 years of age, no significant improvements were shown. This evidence is in accordance with the estimated performance curve found for dribbling speed in our study.

The observed improvements for passing skill are generally consistent with the performances of recent research in 270 talented young players in the Netherlands (Huijgen, Elferink-Gemser, Ali, & Visscher, 2013). The predicted time to complete the Loughborough Soccer Passing Test improved over the years (18%), while the skill performance time (involving a combination of passing accuracy and control of the ball) improved to an even greater extent (32%). This suggests that development in a more complex task is probably related to accuracy rather than speed of movement alone. However, the estimated performance curve assumes a rectilinear trend, in contrast to the above mentioned research. It's possible that these differences in tempo of development are related to the nature of the passing tests considered in both studies.

While the present study highlighted the importance of annual volume of training in the development of aerobic performance and soccer-specific skills, this indicator might not be sensitive enough. A clarification of training related activities (e.g. goalkeeping-specific, integrated, strength and conditioning) and its quantification may provide a clearer understanding about performance characteristics in soccer goalkeepers. Trainers and coaches can benefit from the use of multilevel models in order to predict the development of their goalkeepers and compare with the performance curves in our sample, i.e., to locate a goalkeeper in the estimated performance curves and determine if he is performing above or below average for his age and which factors may be responsible (Huijgen et al., 2010). It should be noted, however, that the known protocols for skill-related performance are of limited use when testing the goalkeeper given the unique technical demands of his actions and position-specific test measures should be developed. Furthermore, it is also important to recognize that the most decisive actions during a soccer game, such as sprinting, changing of direction, jumping and diving, consist in the ability to generate several maximal short-term efforts (Di Salvo et al., 2008; Sainz de Baranda P., 2008).

3.2.6. Conclusion

Developmental changes in aerobic performance and soccer-specific skills were explained by different predictors. Annual volume of training was an important contributor to explain variance in soccer-specific skills, while age was a consistent source of variation in all performance indicators. Further, the time and tempo of development differed. Applying multilevel models in youth soccer provides trainers and coaches valuable information about goalkeepers development and which factors may be responsible. Although literature regarding playing-position variation has recognized the importance aerobic performance and soccer-specific skills in youth goalkeepers, future research should include the development of goalkeeping-specific test measures and maximal short-term efforts.

3.2.7. Acknowledgements

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3.2.8. References

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Chapter 4

Short-Term Maximal Efforts

4.1. Study 3 (Pilot study)

R

Reproducibility of Estimated Peak Output in the Force-Velocity Test derived from multiple 10-s maximal sprints in the cycle-ergometer

Submitted

4.1.1. Summary

The study was aimed to examine the reproducibility of estimated peak output and estimated pedal velocity in a 10-s all out cycling test in 22 physical education students aged 23.50±4.73 years. All participants performed a force-velocity test on a friction-braked ergometer on two separated occasions. No significant differences were found between session 1 (897.6W, 142.2rpm) and session 2 (905.7W, 141.7rpm) for mean optimal outputs (p>0.05). Test-retest results showed good reliability for estimated peak output (TEM = 31.9W, %CV = 3.5, ICC = 0.986) and pedal velocity (TEM = 5.4rpm, %CV = 3.8, ICC = 0.924). Short-term maximal testing can help coaches and practitioners to monitor athletes' response and development to training programs.

Keywords: *short-term maximal effort; intra-class correlation; reliability*

4.1.2. Introduction

The force-velocity relationship was firstly discussed by Hill (A. V. Hill, 1922) and later by Lupton (Lupton, 1922). It was found an inverse association between the amount of work performed and shortening velocity. Later, the original author (A. Hill, 1938) described the relationship between force and velocity with a hyperbolic equation, suggesting that maximal voluntary contractions correspond to optimal values of load and velocity. Consequently, mechanical performance is often summarized by plotting the velocity of a shortening muscle as a function of the load (Seow, 2013). A force-velocity curve is usually obtained from a curve-fitting of force-velocity data, resulting from the use of a friction-braked cycle ergometer. An optimal protocol for the estimation of maximal power from single all-out cycling exercises is gaining popularity (Driss & Vandewalle, 2013; H. Vandewalle, Peres, & Monod, 1987).

The Wingate Anaerobic Test (WAnT) is probably the most popular short-term maximal test in a cycle ergometer (Van Praagh & Dore, 2002). It was developed during the 1970's at the Department of Research and Sport Medicine of the Wingate Institute for Physical Education and Sport in Israel (Bar-Or, 1987). An alternative to WAnT is provided by a set of all-out sprints against a range of braking forces: the Force-velocity test (FVT). The FVT is based on the hyperbolic force-velocity relationship and on the quasi-linear relation between pedal rate and braking force. These relationships enable the optimal velocity and braking force (Fb) for optimized peak output to be estimated for each subject (Chia & Armstrong, 2007).

The FVT protocol described by Santos and colleagues (Santos, Welsman, De Ste Croix, & Armstrong, 2002) involved a series of four to six maximal exercise bouts against a variety of braking forces randomly selected (range 0.030 to 0.110 $kg \cdot kg^{-1}$). Each sprint initiated from a rolling start (60rpm, minimal resistance) and was immediately stopped when the optical sensor of the ergometer detected three consecutive declines in pedal revolutions. One minute of active recovery and four minutes stationary rest were allowed between each episode. Furthermore, this study reported a reliability coefficient of 51W and a coefficient of variation of 3.0% in optimal peak output. Critical aspects in this protocol emerged the number of all-out sprints, time and type of recovery between episodes, randomization of Fb, standardization of warm-up procedures and flywheel inertia (Driss, Vandewalle, Le Chevalier, & Monod, 2002; Linossier, Dormois, Fouquet, Geyssant, & Denis, 1996; H.

Vandewalle, Peres, Heller, Panel, & Monod, 1987; Winter, Brown, Roberts, Brookes, & Swaine, 1996).

More recently, the reproducibility of performance parameters obtained from a 10 s maximal cycling effort at different sampling rates (1Hz and 50Hz) was investigated in 48 young adult athletes (Duarte et al., 2014). However, the reproducibility of the estimated peak output obtained from a series of 10 s all-out cycling exercises is still lacking. The purpose of this study was to examine the reproducibility of estimated optimal outputs derived from a force-velocity test performed on a cycle-ergometer. The present study considered the reproducibility peak output and pedal velocity provided by a series of short all-out sprints against a range of braking forces on a friction-braked cycle ergometer.

It was expected that optimal outputs obtained from FVT would be reproducible between 2 trials sessions in active adults.

4.1.3. Method

Participants

The reproducibility in optimal outputs was evaluated in 22 adults aged 23.50±4.73 years, with previous or current experience in sport (9.86±5.93 years) (soccer, paintball, canoeing, roller hockey, athletics, figure skating, swimming, futsal, judo, handball and underwater hockey). Participants were all physical education students.

Measures

All anthropometric measurements were assessed by a single trained observer following the protocols described by Lohman and colleagues (Lohman, Roche, & Martorell, 1988). A portable stadiometer (Harpenden model 98.603, Holtain LTD, Crosswell, UK) and sitting height table (Harpenden, Holtain LTD, Crosswell, UK) were respectively used to measure height and sitting height to the nearest 0.1 cm. Body mass was measured with a portable balance (Seca model 770, Hanover, MD, USA) to the nearest 0.1 kg. Thirteen male students withdrawn from the total sample were measured twice for anthropometry, each separated by one week. Technical errors of measurement (TEM) based on the replicates were calculated for all anthropometric dimensions (Malina, Hamill, & Lemeshow, 1973). Based on these replicate measures, technical error of measurement (TEM) was 0.37 cm for height (%CV=0.21), 0.56 kg for body mass (%CV=0.81%) and 0.71 cm for sitting height (%CV=0.76%).

Circumferences at the gluteal furrow (highest possible horizontal circumference), middle thigh (largest possible mid-thigh circumference), distal thigh (minimum circumference above the knee), and lengths between each circumference level were measured and afterwards used to estimate total thigh volume of the dominant leg. The protocol was originally presented for total lower limb volume (Jones & Pearson, 1969) and was recently validated for late adolescent rugby players (Carvalho et al., 2012) and circumpubertal boys and girls (Coelho-e-Silva et al., 2013). Data quality followed the same procedures as mentioned before for body size and TEM was 0.64 cm for proximal thigh circumference (%CV=1.16), 0.78cm for mid-thigh circumference (%CV=1.53), and 1.04 cm for distal circumference (%CV=2.82). Corresponding parameters for front and posterior thigh skinfolds were respectively 1.39 mm (%CV=11.90) and 1.27 mm (%CV=13.43). The skinfolds were used to obtain fat-free cross-sectional areas and therefore to obtain an estimate of fat-free thigh volume (Carvalho et al., 2012).

The air displacement plethysmography technique was used to assess body volume (Bod Pod® Body Composition System, Life Measurement Instruments, Concord, CA). Residual thoracic volume was estimated as proposed by the manufacturer. Total body density was calculated by the operating procedures previously described (Dempster & Aitkens, 1995) and was subsequently converted to percent fat using the age specific equations assumed by the software (for all participants the Siri equation was automatically assumed).

A standardized warm up was performed using a friction-loaded cycle ergometer (Monark 894E Peak Bike, Monark AB, Vargerg, Sweden) interfaced with a microcomputer and calibrated for pedal speed and applied resistance. Warm up consisted in 4-min pedaling with minimal resistance (basket supported) at 60 rev $\cdot$ min^{-1} interspersed with three all-out sprints of 2 to 3 s followed by static stretching of the hamstrings, quadriceps and adductor muscles of the hip. Cycle-ergometer tests began with minimal resistance (basket supported) at 60 rev $\cdot$ min^{-1}. At the verbal sign “3-2-1, go” subjects started to pedal as fast as possible while the resistance was abruptly applied and the computer activated simultaneously. Participants remained seated during the tests and were verbally encouraged to give an all-out effort throughout the tests.

The force-velocity test (FVT) involved a set of 3-5 maximal bouts of 10 s trials against a range of braking forces (0.050 to 0.100 $kg \cdot kg^{-1}$; initial braking force [Fb] set at 0.075 $kg \cdot kg^{-1}$ with subsequent Fb above and below this intensity – randomly). Five minutes of active recovery (60 $rev.min^{-1}$, unloaded) were allowed between each trial. A polynomial equation derived from the interpolation of peak outputs, pedal velocity and Fb was used to obtain estimated peak output and pedal velocity.

Procedures

This cross-sectional study was an extracted part of a research proposal granted and funded by the Portuguese Foundation for Science and Technology [SFRH/BD/72111/2010]. Each participant visited the laboratory located in Coimbra University Stadium in two occasions, with one week apart between testing sessions. All assessments were performed at the same hours of the day (10:00–12:00 a.m.).

Participants were instructed not to eat for at least 3 h before testing and not to drink coffee or beverages containing caffeine for at least 8 h before testing. Participants were fully informed about the nature of the study, objectives and procedures related to data collection. They were also informed that their participation was voluntary and they could withdraw from the study at any moment. The research proposal was approved by the Scientific Committee of the University of Coimbra and standards research in sports medicine were considered according to the Declaration of Helsinki.

Analysis

Descriptive statistics for chronological age (CA), training experience, body size and estimated optimal variables were computed for the total sample. The assumption of normality was checked using the Shapiro-Wilk test. Means and standard deviations were calculated for each time moment and also mean difference between sessions. Differences between repeated measurements were examined with paired T-test analysis and effect sizes estimated (Rosnow & Rosenthal, 1996). The association between repeated measurements was determined using Pearson's coefficients of correlation (r). Reliability was determined using technical error of measurement (TEM), reliability coefficients (R) and coefficients of variation (%CV). Intra-class correlation coefficients (ICC) and respective 95% confidence intervals were also calculated. The limits of agreement between sessions were also assessed by plotting the mean differences between sessions according to the Bland-Altman procedures (Bland & Altman, 1986). Bivariate coefficients of correlation were determined to inform about the association between the mean, differences and modulus of repeated measures in estimated peak output (OFb). Confidence intervals (CI) were set at 95%. Coefficients were interpreted as recommended (Hopkins, Marshall, Batterham, & Hanin, 2009): trivial ($r < 0.1$), small ($0.1 < r < 0.3$), moderate ($0.3 < r < 0.5$), large ($0.5 < r < 0.7$), very large ($0.7 < r < 0.9$), nearly perfect ($r > 0.9$) and perfect ($r = 1$). Statistical significance was set at $p < 0.05$ and all analyses were carried out using the Statistical Package for the Social Sciences for Windows (SPSS v.22.0, Chicago, IL, USA).

4.1.4. Results

Chronological age (CA), training experience and anthropometric characteristics of the total sample, estimated optimal outputs derived from the FVT are summarized in Table 4.1 separately for sessions 1 and 2. From session 1 to session 2 estimated peak output (OFb) slightly increased (8.1 watts), while estimated pedal velocity remained constant (0.6 rpm).

Estimated optimal outputs ($p = 0.416$, ES = 0.178; $p = 0.764$, ES = 0.066) were also quite similar between sessions (Table 4.2). Reproducibility statistics for estimated peak output (OFb) and estimated pedal velocity (OFb) are presented in Table 4.3 and Figure 4.1 illustrates the Bland-Altman plots. Bivariate correlations between repeated measures were high and significant ($r > 0.865$; $p < 0.01$). Test-retest analyses are quite similar for the estimated optimal outputs: estimated peak output (OFb) (TEM = 31.9; R = 0.982; ICC = 0.986; LOA = -81.010 to 97.209) and estimated pedal velocity (OFb) (TEM = 5.4; R = 0.907; ICC = 0.924; LOA = -15.729 to 14.720). Data also indicated a within-subject variance of 3.5% and 3.8%, respectively.

Table 4.1. Descriptive statistic for the total sample (n=22).

	Range		Mean			Standard deviation	Shapiro-Wilk	
	Minimum	Maximum	Value	SE	(95% CI)		Value	*p*
Chronological age, years	18.72	35,28	23,50	1,00	(21.40 to 25.60)	4.73	0.828	0.001
Training experience, years	2.00	27.00	9.86	1.26	(7.23 to 12.49)	5.93	0.913	0.056
Height, cm	165.1	179.3	172.9	0.91	(171.0 to 174.8)	4.3	0.939	0.187
Sitting height, cm	87.9	96.8	92.3	0.6	(91.1 to 93.5)	2.7	0.936	0.165
Leg length, cm	75.6	85.0	80.6	0.5	(79.5 to 81.8)	2.6	0.970	0.714
Weight, kg	49.5	104.9	70.4	2.8	(64.7 to 76.2)	13.0	0.957	0.438
Fat mass, %	3.6	34.6	16.7	1.9	(12.8 to 20.6)	8.7	0.941	0.209
Fat mass, kg	2.1	36.6	12.1	1.7	(8.5 to 15.7)	8.2	0.871	0.008
Fat-free mass, kg	38.8	72.5	58.0	2.1	(53.7 to 62.3)	9.6	0.887	0.017
Thigh volume, L	3.30	7.00	4.90	0.19	(4.50 to 5.30)	0.90	0.960	0.491
Session 1								
Estimated peak output (OFb), watts	500.1	1271.5	897.6	41.0	(812.3 to 983.0)	192.5	0.936	0.163
Estimated pedal velocity (OFb), rpm	113.1	168.7	142.3	2.9	(136.1 to 148.3)	13.8	0.977	0.858
Session 2								
Estimated peak output (OFb), watts	497.0	1268.1	905.7	41.6	(819.3 to 992.1)	194.9	0.944	0.239
Estimated pedal velocity, rpm	185.1	141.7	141.7	3.3	(134.9 to 148.5)	15.4	0.939	0.189

Table 4.2. Mean and standard deviation at each trial session and estimated optimal outputs, mean differences between sessions and respective 95% confidence intervals of paired T-Test (n=22).

	Session 1	Session 2	Mean difference		*t*	df	*p*	ES
	Mean ± sd	Mean ± sd	Value	(95% CI)				
Estimated peak output (OFb), watts	897.6 ± 192.5	905.7 ± 194.9	-8.1	(-28.2 to 12.1)	-0.831	21	0.416	0.178
Estimated pedal velocity (OFb), rpm	142.2 ± 13.8	141.7 ± 15.4	0.5	(-2.9 to 3.9)	0.305	21	0.764	0.066

Table 4.3. Correlation between trial sessions, technical error of measurement (TEM), coefficient of reliability (*R*), coefficient of variation (%CV) and intra-class correlation coefficient (ICC) (n=22).

	Coefficient of correlation			Reliability			ICC	
	r	(95% CI)	*p*	TEM	R	%CV	Value	(95% CI)
Estimated peak output (OFb), watts	0.972	(0.916 to 0.994)	0.000	31.9	0.982	3.5	0.986	(0.966 to 0.994)
Estimated pedal velocity (OFb), rpm	0.865	(0.697 to 0.941)	0.000	5.4	0.907	3.8	0.924	(0.818 to 0.969)

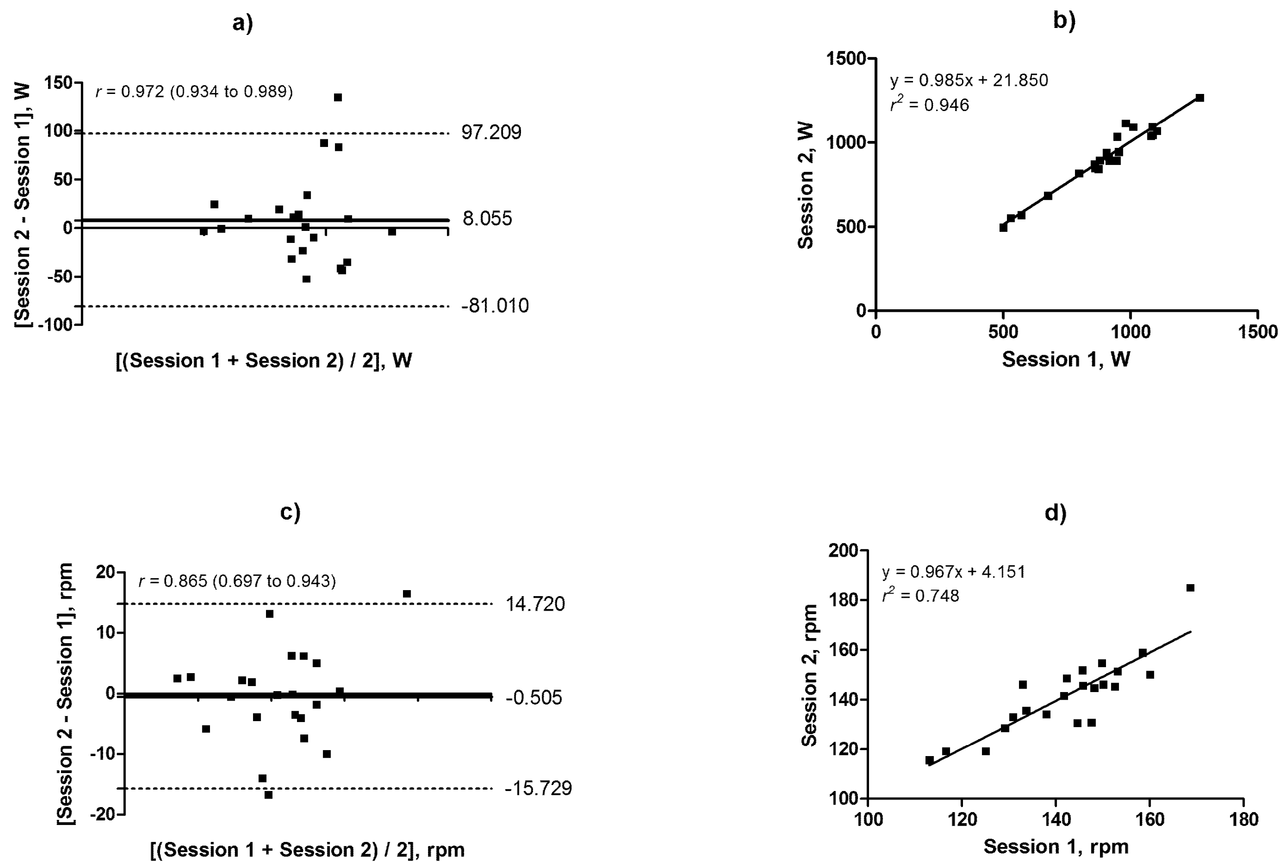

Figure 4.1. Bland-Altman plot between sessions for estimated peak output (OFb) (panel a) and estimated pedal velocity (OFb) (panel c). Linear regression between session 1 and session are also presented in panel b and panel c, respectively (n=22).

Table 4.4. Bivariate correlations between the means, the differences and the modulus of two trial sessions in estimated peak output with chronological age, training experience and anthropometric characteristics (n=22).

(X_i: variables)	Estimated peak output (OFb), watts					
	Y1: mean		Y2: session 2 – session 1		Y3: √(session 2 – session 1)^2	
	$r_{(xi,y1)}$	(95% CI)	$r_{(xi,y2)}$	(95% CI)	$r_{(xi,y3)}$	(95% CI)
X_1: Chronological age, years	0.131	(-0.317 to 0.452)	-0.440*	(-0.765 to 0.195)	0.383	(-0.363 to 0.740)
X_2: Training experience, years	0.125	(-0.410 to 0.550)	-0.045	(-0.390 to 0.339)	-0.032	(-0.411 to 0.329)
X_3: Height, cm	0.480*	(0.132 to 0.741)	-0.008	(-0.392 to 0.443)	0.234	(-0.089 to 0.517)
X_4: Leg length, cm	0.353	(-0.074 to 0.683)	-0.132	(-0.502 to 0.323)	0.260	(-0.114 to 0.509)
X_5: Weight, kg	0.728*	(0.507 to 0.939)	-0.335	(-0.627 to 0.382)	0.563*	(0.161 to 0.799)
X_6: Fat mass, kg	0.134	(-0.308 to 0.406)	-0.547*	(-0.787 to -0.043)	0.445*	(-0.256 to 0.712)
X_7: Fat-free mass, kg	0.882*	(0.711 to 0.959)	0.004	(-0.322 to 0.495)	0.396	(0.172 to 0.650)
X_8: Thigh volume, L	0.456*	(0.165 to 0.725)	-0.257	(-0.604 to 0.350)	0.352	(-0.176 to 0.635)

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

A significant association between the mean estimated peak output (OFb) and anthropometric characteristics was showed, particularly for height (r = 0.480), weight (r = 728), fat-free component (r = 0.882), and thigh volume (r = 0.456), while the difference between sessions in this variable was significantly correlated with CA (r = -0.440) and fat mass (r = -0.547). The modulus of two trial sessions was significantly correlated with weight (r = 0.563) and fat mass (r = 0.445).

4.1.5. Discussion

The current study examined the expression of optimized power outputs depending on the estimation of optimal braking forces in a force-velocity test on a cycle-ergometer (FVT). The main finding of our results was in agreement with the expeted: the estimated peak output (OFb) and estimated pedal velocity (OFb) were reproducible between 2 trials sessions, in active adults. The FVT assumes that the production of peak outputs can be optimized by a series of brief maximal effort sprints against a range of braking forces, providing a promising alternative for investigation in short-term maximal testing (Driss & Vandewalle, 2013; Driss, Vandewalle, & Monod, 1998; H. Vandewalle, Peres, Heller, et al., 1987). Comparisons between peak outputs derived the FVT and the WAnT showed that the use of a fixed applied force of 0.075 kg · kg^{-1} may not be optimal for eliciting anaerobic peak outputs, as this common braking force tended to underestimate peak output and pedal velocity in 10 recreational and 10 highly trained adults (H. Jaafar, Rouis, Attiogbe, Vandewalle, & Driss, 2015), as well as in young male soccer goalkeepers (Rebelo-Gonçalves et al., 2014).

Previous authors recommended a habituation session in order to obtain reproducible measures in adults and after (Doré et al., 2003), whereas the use of paired samples T-test detected no differences between 2 trials sessions in our study. The reliability results between session 1 and session 2 of a 6 s repetitive short maximal cycling test showed lower values of CV for adult men and women in peak output (2.63% and 3.71%) and pedal velocity (1.89% and 2.88) (Hamdi Jaafar, Attiogbé, Rouis, Vandewalle, & Driss, 2015). Similarly, values of ICC were also lower when compared to our sample (0.97 and 0.97; 0.79 and 0.80). Test-retest correlation was similar with our study (0.97 and 0.97; 0.89 and 0.82). In another study, it was concluded that with three sprints a coefficient of variation lower than 3.0% was obtained in children as well as in female and male adults performed five tests of four all-out sprints against four standardized braking forces (Doré et al., 2003). Therefore, in order to obtain reliable data from a FVT in active adults, a three all-out exercise is advised, being a familiarization session less important is these samples.

Predictors of short-term maximal testing highlighted the importance of body size and muscle mass both in children and in adults. Variance in peak output assessed by WAnT was explained in 52% by maturity, leg length and body mass in basketball players aged 14–16 years (Carvalho et al., 2011). Furthermore, developmental changes in optimal peak output calculated in boys and girls aged 12–14 years, were largely explained by increases in thigh volume alongside weight and height with neither age nor gender having a significant effect on peak output (Santos, Armstrong, De Ste Croix, Sharpe, & Welsman, 2003). Other sources of variation have also been considered in adults, recognizing the importance of quantitative and qualitative factors (Driss & Vandewalle, 2013). The active muscle mass involved during maximal exercise is the main quantitative factor, which is in agreement with our results. In fact, height, leg length, fat-free mass and thigh volume were significantly and positively associated to estimated peak outputs. Qualitative factors such as fast fibre percentage, mechanical efficiency and motor control have not been considered in the present study.

The significant contribution of short-term muscle power in sporting activities in which power is dominant, makes this a necessary feature in successful athletes. For example, anaerobic power and capacity values assessed by the WAnT protocol were higher in sports such as volleyball, basketball, hockey, boxing, and wrestling (Popadic Gacesa, Barak, & Grujic, 2009). Although there is a lack of a relevant 'gold standard', both field and laboratory-based performance have been widely used to measure power outputs of all-out tests in applied science and are generally well correlated (H. Vandewalle, Peres, & Monod, 1987). Comprehensive reviews (Driss & Vandewalle, 2013; Van Praagh & Dore, 2002; Henry Vandewalle & Driss, 2015) emphasized the use of a common braking force as one of the major limitations to WAnT, not satisfying the muscle force-velocity relationship in specific populations (e.g., adults and groups of athletes). In our study, braking forces ranged from 2.7 kg to 8.4 kg and from 5.0% to 10.0% between trials. While the specificity of WAnT for athletes in non-cycling sports has not been established, fatigue index was significantly higher in 41 local roller hockey players compared to 32 international under-17 players (Coelho-Silva et al., 2012). Relative mean power and fatigue index were also able to discriminate soccer goalkeepers from outfield players, in particular defenders and midfielders (Nikolaidis, 2014). Thus, even taking into account its limitations, particularly in the accuracy of peak power output, the use of WAnT as a laboratory-based method might prove to be useful to evaluate and monitor an individual's adaptation and changes in maximal intensity short-term performance.

In summary, optimal outputs derived from the FVT has proven to be reproducible in active adults. The present study have only considered peak output and pedal velocity determined by optimal Fb, not taking into account other possible variables such as explosive power. Future research should focus on the agreement between the FTV and WAnT, bearing in mind the known advantages of mean power and fatigue index. Other limitations include a possible fatigue effect in 10-s all out sprints, even if a 5-min period or recovery is allowed. As a consequence, the FVT is time consuming. Short-term maximal testing usually reports acceptable reliability but its predictive power and transferability for talent identification programs is not consistent. Instead of relying in multidimensional tests to select or exclude an athlete, focus should remain in nurturing players' strengths and improve areas of weakness (Pearson, Naughton, & Torode, 2006), i.e., monitoring the individual response and development to training programs.

4.1.6. References

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4.2. Study 4

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Maximal Intensity Short-term Performance in Soccer Goalkeepers: Variation by Competitive Level

Submitted

4.2.1 Abstract

Goalkeeping highlights short-term efforts when the goalkeeper is directly involved in play. This study compared maximal intensity short-term performance in 33 young soccer goalkeepers of different levels. Training experience and chronological age was recorded. Height, sitting height, body mass and thigh volume were measured. Body composition was estimated using air-displacement plethysmography. Laboratory-based assessments included two all-out protocols performed on a friction-braked ergometer: the Wingate Anaerobic Test (WAnT) and the Force-Velocity Test (FVT). Isokinetic dynamometry of knee extensors and flexors at $60°\cdot s^{-1}$ *and* $180°\cdot s^{-1}$ *was also examined. Comparisons between goalkeepers competing in the national youth leagues and in regional divisions revealed significant differences for training experience, WAnT mean output, knee flexors at both angular velocities and for the conventional ratio at* $180°\cdot s^{-1}$*. The linear combination of three predictors (training experience, ratio knee flexors to knee extensors at* $180°\cdot s^{-1}$ *and WAnT: pedal velocity) was able to correctly predict 87.9% of goalkeepers into the original groups. This findings suggest that the WAnT can provide coaches and practitioners more relevant information about training adaptations, unlike the proposed FVT protocol. Similarly, strength in the knee flexors play an important role in goalkeeping and systematic training is required. It seems that the most important strength factor in goalkeeping is not of the maximal kind but functional from different positions. Nevertheless, the question whether these differences are a function of coach selection, of having access to long-term training programs considering this particular playing position, or both remains unclear.*

Keywords: *youth, football, anaerobic power, testing*

4.2.2. Introduction

The specific nature of contemporary soccer requires goalkeepers to excel in a wide range of physical, technical and tactical behaviours, and to possess particular anthropometric and physiological characteristics since youth. Recent findings, reported that goalkeepers are taller, heavier and have higher values of fat mass than outfield players (1, 2), even at the age of 8 years (3). Furthermore, playing position-related variation consistently showed that goalkeepers are outperformed by defenders, midfielders and forwards in agility and endurance (4-6).

While the movement patterns are mainly characterized by long periods of low intensity, goalkeepers are required to perform high intensity actions (7) like sprinting, diving, jumping, catching or throwing, most of them with an explosive nature (8). The success and effectiveness of these actions rely, among other factors, in the athletes' ability to generate mechanical energy from energy sources obtained by anaerobic process. Power production during short-term efforts is limited by the rate at which energy is supplied by ATP (adenosine triphosphate) yield by the whole organism (9). However, several ethical and methodological constraints can be presented when making direct measurements of either the rate or the amount of energy obtained by anaerobic process. Although there is a lack of a relevant 'gold standard', both laboratory-based and field-based methods have been used to measure power outputs of all-out tests and are generally well correlated (10).

Maximal intensity short-term performance is commonly assessed on a friction-braked ergometer, despite recognizing several technical, methodological and biological factors affecting maximal anaerobic power (9, 11). One of the most extensively used test is the Wingate Anaerobic Test (WAnT), consisting in pedaling with maximal effort for 30 seconds against a standardized constant braking force ($0.075 \text{ kg} \cdot \text{kg}^{-1}$ or $0.74 \text{ N} \cdot \text{kg}^{-1}$). Even though the WAnT has shown to be highly valid and reliable with test-retest coefficients ranging between 0.89 and 0.97 (12), one of the major limitations is that force of external resistance might not satisfy the muscle force-velocity relationship, particularly in youth populations and athletes. An alternative to the WAnT protocol is provided by a series of all-out sprints against a range of braking forces: the Force-velocity test (FVT). The FVT is based on the hyperbolic force-velocity relationship and on the quasi-linear relation between pedal rate and braking force. A detailed description of the commonly used procedures can be found elsewhere (11, 13). Generally obtained in adults (14) and children (15), hardly any information is available in young soccer players considering the FVT. Isokinetic dynamometry is frequently used to monitor muscular strength in soccer players and it's widely accepted as clinically relevant for assessing deficits and imbalances in muscle strength, i.e. knee function and stability (16). These apparatus allows to determine torque-velocity curves in isokinetic movements and joint-angle curves in a series of isometric contractions.

Applied research showed that goalkeepers were differentiated according to competitive level (17), selection process (4) and relevance for competition success (6) in anthropometric and physiological characteristics, although no significant differences were verified. Among a total sample of 296 young male soccer players who performed the 30-s WAnT (18), goalkeepers exhibited the highest peak power when compared to outfield players, but significant differences were only found for mean power relative to body mass and fatigue index. A study carried out with 23 goalkeepers who ultimately joined professional clubs (19) found significantly greater differences for body mass, sprint performance, maximal anaerobic power output (derived by the recorded time over the last 10-m of the fastest 40-m sprint) and peak concentric torque of knee flexors. Nevertheless, the effect of competitive level in maximal intensity short-term performance it's still not clear among goalkeepers.

The purpose of this study was to examine peak outputs derived from cycle ergometer and isokinetic dynamometry in young goalkeepers by competitive levels. It was hypothesized that goalkeepers competing at a national level would obtain better performances in the WAnT, FVT and isokinetic strength of knee extensors and flexors.

4.2.3. Methods

Procedures

The research proposal was approved by the Scientific Committee of the University of Coimbra and standards research in sports medicine were considered according to the Declaration of Helsinki. Parents or legal guardians provided written consent and clubs and participants were fully informed about the nature of the study, objectives and procedures related to data collection. In addition, goalkeepers were informed that participation was voluntary and that they could withdraw from the study at any moment.

This study was part of a research proposal granted and funded by the Portuguese Foundation for Science and Technology [SFRH/BD/72111/2010]. Each participant performed three visits to the laboratory located in Coimbra University Stadium. All testing procedures were completed during the preseason period (August and September) with at least 48 h between testing sessions and all assessments were performed at the same hours of the day (5:00–7:00 p.m.). Participants were instructed not to eat for at least 3 h before testing and not to drink coffee or beverages containing caffeine for at least 8 h before testing. Participants were also instructed to wear the similar clothing and footwear on each testing occasion

Sample

The sample included 33 young male soccer goalkeepers divided into two groups according to their competitive level during the seasons of 2011–2012 and 2012–2013: national group (n = 17), competing in the national youth leagues organized by the Portuguese Soccer Federation; and local group (n = 16), competing in a regional division organized by the respective Regional Soccer Associations. None of the subjects reported recent injuries. Chronological age (CA) was calculated to the nearest 0.01 year by subtracting birth date from date of testing. Exposure to systematic training (i.e. experience in soccer in years) was obtained by interview.

Body size

Anthropometry was assessed by a single trained observer following standard procedures (20). Height and sitting height were measured respectively with a portable stadiometer (Harpenden model 98.603, Holtain LTD, Crosswell, UK) and sitting height table (Harpenden, Holtain LTD, Crosswell, UK) to the nearest 0.1 cm. Body mass was measured with a portable balance (Seca model 770, Hanover, MD, USA) to the nearest 0.1 kg. Based on replicate measures assessed in an independent sample of 13 male students aged 20.8±2.1 years, technical error of measurement (TEM) was 0.37 cm for stature (%CV=0.21), 0.56 kg for body mass (%CV=0.81%) and 0.71 cm for sitting height (%CV=0.76%).

Thigh volume

Circumferences at the gluteal furrow (highest possible horizontal circumference), mid-thigh (largest possible mid-thigh circumference), lower thigh (minimum circumference above the knee), and lengths between each circumference level were measured and afterwards used to estimate total thigh volume of the dominant leg. This protocol was originally presented for total lower limb volume (21) and was recently validated for late adolescent rugby players (22) and circumpubertal boys and girls (23). Data quality followed the same procedures as mentioned before for body size and TEM was 0.64 cm for proximal thigh circumference (%CV=1.16), 0.78cm for mid-thigh circumference (%CV=1.53), and 1.04 cm for distal circumference (%CV=2.82). Corresponding parameters for front and posterior thigh skinfolds were respectively 1.39 mm (%CV=11.90) and 1.27 mm (%CV=13.43). The skinfolds were used to obtain fat-free cross-sectional areas and therefore to obtain an estimate of fat-free thigh volume (22).

Air displacement plethysmography

The Bod Pod® Body Composition System (Life Measurement Instruments, Concord, CA) was used to assess body volume. Residual thoracic volume was estimated as proposed by the manufacturer. Afterwards, total body density was computed by the operating procedures described elsewhere (24). Total body density was converted to percent fat using the age specific equations assumed by the software (usually Lohman, except when participants had more than 18 years old and Siri equation was assumed).

Maximal intensity short-term performance

This study considered three assessments of power output. Before the completion of all protocols, a standardized warm up was performed using a friction-loaded cycle ergometer (Monark 894E Peak Bike, Monark AB, Vargerg, Sweden) interfaced with a microcomputer and calibrated for pedal speed and applied resistance. Warm up consisted in 4-min pedaling with minimal resistance (basket supported) at 60 rev · min^{-1} interspersed with three “all-out” sprints of 2-s to 3-s followed by static stretching of the hamstrings, quadriceps and adductor muscles of the hip. Cycle-ergometer tests began with minimal resistance (basket supported) at 60 rev · min^{-1}. At the researcher signal "3-2-1, go" subjects started to pedal as fast as possible while the resistance was abruptly applied and the computer activated simultaneously. Participants remained seated during the tests and were verbally encouraged to give an all-out effort throughout the tests.

The Wingate anaerobic test (WAnT) involved pedaling on a cycle ergometer against a constant braking force set as 0.075 kg·kg^{-1} of body mass. Measurements included peak output (highest mechanical power generated in any 5-s period, expressed in watts), mean output (average mechanical power for the 30-s period, watts), explosive power (watt·s^{-1}) given by the ratio obtained from peak power and time of when the peak power is reached (25), and pedal velocity (rpm).

The Force-velocity test involved a set of 3-5 maximal bouts of 10-s trials against a range of braking forces (0.039 to 0.130 kg·kg^{-1}; initial braking force [Fb] set at 0.075 kg·kg^{-1} with subsequent Fb above and below this intensity – randomly). Five minutes of active recovery (60 rev.min-^{1}, unloaded) were allowed between each trial. The output variables in the FVT were estimated using a polynomial equation that is based on the interpolation of peak outputs and Fb: optimal peak output (watts) and pedal velocity (rpm).

Isokinetic concentric knee extension and flexion of the dominant leg were measured using a calibrated dynamometer (Biodex System 3, Shirley, NY, USA) at angular velocities of 60º·s^{-1} (~1.05 rad·s^{-1}) and 180º·s^{-1} (~3.14 rad·s^{-1}). Each participant was asked to sit on the dynamometer seat with his back reclined at 85º and a standard stabilization strapping was placed across the trunk, waist, and distal femur. Participants were also instructed to maintain their hands crossed on their shoulders while testing. In the concentric action, participants were encouraged to continuously push the arm lever during extension and pull during flexion as hard and fast as possible. Each participant performed five continuous maximal repetitions at each angular velocity. Visual feedback of moment versus time was provided during the test, but no verbal feedback was given (26). Raw data was exported and analyzed with Windows-based software (Acqknowledge, Biopac Systems Inc., v. 4.1, Santa Barbara, CA, USA). Maximal knee extension and flexion peak torque were expressed in N·m and conventional isokinetic strength ratio (knee flexion peak torque/knee extension peak torque) calculated at 60º·s^{-1} and 180º·s^{-1}.

Statistical analysis

The assumption of normality was checked by the Kolmogorov-Smirnov test and by visual inspection of normality plots. Descriptive statistics for training experience, chronological age, morphology and performance outputs in short-term maximal intensity protocols were computed for the total sample and by competitive level. Comparisons between local and national goalkeepers were examined using the independent samples t-test. The magnitude of the differences was assessed using standardized mean differences (Cohen effect size) and interpreted with thresholds of 0.20, 0.60, 1.20, 2.0 and 4.0 for trivial, small, moderate, large, very large and extremely large, as suggested by Hopkins (27). Discriminant analysis (stepwise mode) was performed to obtain a linear equation to successfully classify goalkeepers as local or national level based on a reduced number of variables. Statistical significance was set at $p < 0.05$ and all analyses were carried out using the Statistical Package for the Social Sciences for Windows (SPSS v.22.0, Chicago, IL, USA).

4.2.4. Results

Characteristics of the total sample and goalkeepers of contrasting competitive level are summarized in Table 4.5. Goalkeepers competing at a national level were, on average, taller, heavier, had lower values of fat mass and also higher values of fat-free mass. Nonetheless, significant differences were only found for training experience ($p = 0.003$). National goalkeepers consistently outperformed their local peers in power outputs derived from cycle ergometer and isokinetic strength. More specifically, goalkeepers differed in mean output ($p = 0.048$), knee flexors in the concentric mode at both angular velocities ($p = 0.034$; $p = 0.014$), and in ratio knee flexors to knee extensors at $180^{o}\cdot s^{-1}$ ($p = 0.011$).

Table 4.5. Descriptive statistics for chronological age, training, morphology and performance outputs (WAnT, FVT, isokinetic strength) for the total sample and by competitive level including comparisons between local and national.

	Total (*n* = 33)				Comparisons					
	Mean			Sd	Local	National			Effect size	
	value	SEM	(95% CI)		(*n* = 16)	(*n* = 17)	$t_{(31)}$	*p*	*d*	qualitative
Training experience, years	6.0	0.4	(5.1 to 6.9)	2.5	4.8±2.0	7.2±2.4	-3.194	0.003	1.1	moderate
Chronological age, yyears	15.6	0.3	(14.9 to 16.2)	1.9	15.2±1.7	15.9±2.0	-1.063	0.296	0.4	small
Height, cm	173.5	1.2	(171.1 to 175.9)	6.7	172.0±7.8	174.9±5.3	-1.238	0.225	0.4	small
Sitting height, cm	90.1	0.7	(88.7 to 91.4)	3.8	89.0±3.9	91.1±3.5	-1.687	0.102	0.6	moderate
Leg length, cm	83.4	0.6	(82.1 to 84.7)	3.7	83.0±4.2	83.7±3.3	-0.527	0.602	0.2	small
Body mass, kg	65.5	1.8	(61.8 to 69.2)	10.4	64.5±11.3	66.4±9.8	-0.523	0.605	0.2	small
Fat mass, kg	7.4	0.7	(6.0 to 8.9)	4.2	8.3±5.4	6.6±2.5	1.130	0.267	0.4	small
Fat-free mass, kg	58.2	1.6	(54.8 to 61.5)	9.3	56.4±9.4	59.8±9.3	-1.024	0.314	0.4	small
Thigh volume, L	5.04	0.16	(4.71 to 5.37)	0.92	4.90±1.02	5.17±0.84	-0.830	0.413	0.3	small
WAnT: Peak output, W	819	41	(736 to 902)	35	758±224	877±237	-1.481	0.149	0.5	small
WAnT: Mean output, W	539	112	(499 to 578)	112	499±92	576±119	-2.060	0.048	0.7	moderate
WAnT: Explosive power, $W·s^{-1}$	357	46	(264 to 450)	262	269±201	440±290	-1.951	0.060	0.7	moderate
WAnT: Pedal velocity, rpm	138	4	(131 to 145)	20	131±21	144±18	-1.941	0.061	0.7	moderate
FVT: Peak output, W	880	37	(804 to 956)	215	830±184	926±236	-1.301	0.203	0.5	small
FVT: Pedal velocity, rpm	134	3	(129 to 140)	167	135±15	134±18	0.301	0.766	0.1	trivial
Isokinetic PT ($60^o·s^{-1}$): KE_{CC}, N·m	164	8	(148 to 181)	45	153±40	175±49	-1.435	0.161	0.5	small
Isokinetic PT ($60^o·s^{-1}$): KF_{CC}, N·m	84	4	(76 to 93)	24	75±18	93±26	-2.214	0.034	0.8	moderate
Isokinetic PT ($180^o·s^{-1}$): KE_{CC}, N·m	125	5	(114 to 135)	30	118±25	132±32	-1.333	0.192	0.5	small
Isokinetic PT ($180^o·s^{-1}$): KF_{CC}, N·m	69	3	(62 to 76)	20	61±14	77±22	-2.613	0.014	0.9	moderate
Isokinetic PT ($60^o·s^{-1}$): KF_{CC}/KE_{CC}	0.52	0.01	(0.49 to 0.54)	0.71	0.50±0.09	0.53±0.05	-1.104	0.278	0.4	small
Isokinetic PT ($180^o·s^{-1}$): KF_{CC}/KE_{CC}	0.56	0.01	(0.05 to 0.58)	0.08	0.52±0.07	0.59±0.08	-2.706	0.011	1.0	moderate

PT (peak torque); KE_{CC} (knee extensors, concentric mode); KF_{CC} (knee flexors, concentric mode); KF_{CC}/KE_{CC} (ratio knee flexors to knee extensors).

Table 4.6. Summary of discriminant function analysis to predict competitive level (local versus national) in young soccer goalkeepers (n = 33).

Step	Predictor	Wilks' Lambda				*F*			
		Statistic	df1	df2	df3	*Statistic*	df1	df2	*p*
1	Training experience (y)	0.752	1	1	31	10.201	1	31	0.003
2	Isokinetic PT ($180^{o}\cdot s^{-1}$): KF_{CC}/KE_{CC}	0.651	2	1	31	8.044	2	30	0.002
3	WAnT: Pedal velocity, rpm	0.567	3	1	31	7.379	3	29	0.001

Table 4.7. Cross-tabulations (number of cases) of correctly classified by competitive level after discriminant analysis (n = 33).

		Level		Total	χ^2	df	*p*
		Local	National				
Predicted Group for analysis							
	Local	15	3	18	16.733	3	< 0.001
	National	1	14	15			
Total		16	17	33			

Results of the discriminant analysis (Table 4.6) indicated a function of 3 variables – training experience, 180º·s^{-1} KF_{CC}/KE_{CC} ratio and WAnT: Pedal velocity [Wilks' Lambda(3, 1, 31) = 0.567; χ(3, 29)2 = 16.733, $p < 0.001$; Eigenvalue = 0.763; rc = 0.658]. The function accounted for 100% of variance of the inter-group variability. Accordingly, 3 goalkeepers competing at a national level were reclassified as local, while 1 goalkeeper migrated from local to the national group (Table 4.7). Correlations between discriminating variables and standardized canonical discriminant functions were ordered as follows: training experience (0.657), chronological age (0.484), height (0.460), sitting height (0.457), leg length (0.361), body mass (0.369), fat mass (-0.132), fat-free mass (0.495), thigh volume (0.234), WAnT peak output (0.588), mean output (0.451), explosive power (0.337), pedal velocity (0.399), FVT peak output (0.509), pedal velocity (0.380), isokinetic peak torque (60º·s^{-1}) KE_{CC} (0.366), KF_{CC} (0.582), isokinetic peak torque (180º·s^{-1}) KE_{CC} (0.493), KF_{CC} (0.749), KF_{CC}/KE_{CC}: 60º·s^{-1} (0.448), KF_{CC}/KE_{CC}: 60º·s^{-1} (0.556).

4.2.5. Discussion

The present study examined the variation of maximal intensity short-term performance in young soccer goalkeepers of different competitive levels. A superior performance was consistently demonstrated by goalkeepers competing at a national level in all laboratory-based protocols, particularly in isokinetic strength. The linear combination of three predictors (training experience, ratio knee flexors to knee extensors at 180º·s^{-1} and pedal velocity in the 30-s all-out cycle-ergometer protocol) was able to correctly predict 87.9% of goalkeepers into the original groups.

The results of the current study showed moderate differences (0.60 < Cohen's d < 1.20) only for training experience. In contrast, moderate differences have been reported in two Spanish samples where goalkeepers from successful teams were lighter and had lower values of fat mass (6), while selected goalkeepers were taller, lighter and had longer trunks and legs (4), although no significant differences were found in both studies. Contrasting results were found in Greek players where goalkeepers surprisingly presented significant higher values than midfielders for fat-free mass (kg). Nonetheless, it's consensual among many authors that body size can play a decisive role in the development process of young soccer players, particularly among a highly selected and specialized position such as goalkeeper (1, 2, 19, 28). In fact, body size is an important feature in the effectiveness of goalkeeping actions in situations like shots, 1-on-1 challenges, dealing with crosses, or penalty kicks, as the goalkeeper takes a positioning to occupy larger areas of the goal or places additional constrains to the opponent by narrowing down the shooting angle. As an example, a positive relationship between arm-spam and successful saves and deflections can be expected.

The existence of two different selection procedures for a certain position was recently suggested, with the period around peak growth as a critical mark (3). It seems that coaches are orienteering players to particular positions based on anthropometric and soccer-specific skills before peak growth, while anaerobic performance becomes important in later stages of development, at which point elite players tended to have more experience in soccer than their non-elite peers (17). In accordance, exposure to systematic training was a significant factor to discriminate goalkeepers by competitive level in our research. This finding may be due to the fact that up to now, specific training is not systematically available in all clubs and it can be assumed that goalkeepers demonstrating superior performances have access to long-term training programs specifically designed to develop and optimize ones individual potential. However, the question whether this differences are a function of coach/trainer selection per se, dominance of taller and heavier players, or both remains unclear.

The current findings generally support our hypothesis that goalkeepers competing at a national level would obtain better performances in maximal intensity short-term protocols. Moderate differences were found between groups for WAnT mean output, explosive power and pedal velocity. Similarly, local muscular endurance was the anaerobic parameter that discriminated goalkeepers from outfielders (18). Generally, goalkeepers obtain the lowest results in aerobic protocols, which comes with no surprise given their distinct activity profile during a soccer match. Still, several authors recognized that the enhancement of this parameter is essential for a better adaptation and recovery during specific training (4-6). Given the current results for the WAnT mean output, we can infer that goalkeepers from national level are exposed to training sessions more suited to their positional demands. In this sense, data derived from the WAnT protocol can provide coaches and practioners predictive values on cycle-ergometry and relevant information about training adaptations and changes in performance indicators. On the other hand, results from the proposed FVT protocol doesn't seem to be suitable to young soccer goalkeepers, in contrast to the suggestion of

Driss and Vandewalle (11) where "the all-out tests lasting 30 seconds should be replaced with short (5 seconds) all-out tests against different braking forces with 5-minute recovery…".

The present study revealed significant differences for knee flexors in the concentric mode at both angular velocities and ratio knee flexors to knee extensors at $180^{o}\cdot s^{-1}$. In agreement, differences were observed for preferred and non-preferred leg peak torque in knee flexors at $240.2^{o}\cdot s^{-1}$ (~4.19 $rad\cdot s^{-1}$) among goalkeepers who ultimately achieved a professional status and those who remained amateurs (19). The knee flexors muscle group act eccentrically during ball kicking, running or sprinting, by generating tension while lengthening to decelerate knee extension. Consequently, the evaluation of isokinetic eccentric antagonist strength relative to concentric agonist (29) may more accurately reflect typical soccer actions (30). Still, muscular relationship about the knee joint given by the conventional ratio was able discriminate professional soccer players from amateurs (16), except at $300^{o}\cdot s^{-1}$.

A linear combination of 3 variables correctly predicted 87.9% of the goalkeepers into the original groups. Although a recent attempt to predict playing position based on stepwise discriminant function analyses (2) revealed that soccer-specific skills had a strong predictive power in adolescent players, and fat-free mass also contributed in the under-13 and under-15 group, hardly any data is available considering the relevance of competitive level among goalkeepers. Rather than experience per se, it is reasonable to think that as players experience a variability of training related activities (e.g. goalkeeping-specific, integrated, strength and conditioning), distinguishing factors can be identified. Our research also suggests that the most important strength factor in goalkeeping is not that of the maximal kind but functional from different positions, which is supported by previous evidence regarding soccer players (16, 31). It seems that strength in knee flexors play an important role in goalkeeping and a systematic training is required to improve it as this muscle group is highly trainable (30).

An effect of competitive level in maximal intensity short-term performance was observed in this study. However, it is not clear if the observed differences were due to disparity selection criteria for the position, exposure to systematic training, or some combination of both as they might change over time according the contextual settings in the clubs. Future studies should include larger samples and consider variation by age-group. The ecological validity of cycle-ergometry when assessing young soccer players might be questionable, particularly in the WAnT protocol. In fact, a series of short efforts interspersed by brief recovery periods seems to mimic the activity pattern during a soccer match (31). In addition, there is a predominance of concentric actions of the leg muscles in cycle-ergometer all-out testing, limiting the stretch-shortening muscle tension cycle (32). The functional perspective suggested by our results claim the need for eccentric evaluation in both the dominant and non-dominant leg. Finally, quality control in cycle-ergometry should be evaluated considering young soccer goalkeepers. Nevertheless, laboratory-based assessment allows coaches to optimize the training process by monitoring adaptation and changes in maximal intensity short-term performance.

4.2.6. Practical Implications

Goalkeeping highlights anaerobic efforts of short-term duration when the goalkeeper is directly involved in the defensive (set play, shooting, crossing, through ball and 1-on-1 challenges) and offensive (set play, ball in hand, build-ups and back pass) moments. Rather than applying maximal strength, these typical actions are largely related to an optimal use of the available strength on a given time/task. Therefore, goalkeeper specific-training is a key factor for individual performance, particularly in youth soccer. The design of goalkeeper-specific activities must focus on both eccentric and concentric actions, multi-direction movements during deceleration and acceleration to improve the stretch-shortening cycle, jump ability, and agility (33). These activities might include Nordic hamstring, deadlift and lunges (30), single/double leg hop, lateral movements (step ups and shuffles), skipping, squats, low depth jumps and agility footwork.

4.2.7. Acknowledgments

In memory of Filipe Simões, a beloved friend and colleague.

4.2.8. References

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Chapter 5

Goalkeeper-Specific Testing

5.1. Study 5

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Assessment of Technical Skills in Young Soccer Goalkeepers: Reliability and Validity of Two Goalkeeper-specific Tests

In revision: The manuscript was already assessed "changes" and is waiting for the second evaluation by reviewers.

5.1.1. Abstract

The purpose of this study was to evaluate the reproducibility and validity of two new tests designed to examine goalkeeper-specific technique. Twenty-six goalkeepers (14.49 ± 2.52 years old) completed two trial sessions, each separated by one week, to evaluate the reproducibility of the Sprint-Keeper Test (S-Keeper) and the Lateral Shuffle-Keeper Test (LS-Keeper). Construct validity was assessed among forty goalkeepers (14.49 ± 1.71 years old) by competitive level (elite versus non-elite), after controlling for chronological age. All participants were examined in vertical jump (CMJ and CMJ-free arms), acceleration (5-m and 10-m sprint) and goalkeeper-specific technique. The S-Keeper requires the goalkeeper to accelerate during 3 m and dive over a stationary ball after performing a change of direction in a total distance of 10 m. The LS-Keeper involves three changes of direction and a diving save over a stationary ball, in a total distance of 12.55 m. Performance was respectively measured as total time for the right and left sides in each protocol. Bivariate correlations between repeated measures were high and significant (r = 0.835 – 0.912). Test-retest results for the S-Keeper and LS-Keeper showed good reliability (reliability coefficients > 0.88, intra-class correlation coefficient > 0.908 and coefficients of variation < 4.37%), even though participants tended to improve performance when diving to their right side (p < 0.05). Both tests were able to detect significant differences between elite and non-elite goalkeepers, particularly to the left side (p < 0.05). These findings suggest that the S-Keeper and LS-Keeper are reliable and valid tests for assessing goalkeeper-specific technique. Both protocols can be used as a practical tool to provide relevant information about the influence of several components of performance in the overall execution of a diving save, particularly movement patterns, take-off movements and asymmetries.

Key words: *sport specialization, playing position, diving save*

5.1.2 Introduction

Soccer-specific skill tests are contemplated as objective and reliable measures of skill proficiency (see comprehensive reviews (Ali, 2011, Russell and Kingsley, 2011)), while being able to discriminate young soccer players according to playing position, current level or future success (Vaeyens et al., 2006, Reilly et al., 2000, Huijgen et al., 2009, Coelho e Silva M. J., 2010). Recently, dribbling speed, shooting accuracy and passing tests were acknowledged as important discriminating factors between goalkeepers and outfield players, while fat-free mass and ball control entered the model in middle and late adolescence, respectively (Rebelo-Goncalves et al., 2015). Available data considering contrasting groups of goalkeepers (Gil et al., 2007, le Gall et al., 2010, Rebelo et al., 2013) are of limited use when addressing performance characteristics of soccer goalkeepers, since the known protocols do not consistently included suitable players position-specific test measures. Thus, the distinctive technical demands of goalkeeping claim the need for test measures regarding the performance-related characterization of soccer goalkeepers (Ziv and Lidor, 2011).

While the movement patterns are mainly characterized by long periods of low intensity, soccer goalkeepers are required to perform moderate-high intensity multi-directional movements and a number of skilful actions. Accordingly, the average number of sprint actions was reported to be 2 ± 2 with a total distance range between 0 and 15 m, with a higher prevalence of sprints of 0 – 5 m in sixty-two goalkeepers from 28 teams in the English Premier League (Di Salvo et al., 2008). One of the most critical movements involved in goalkeeping is the diving action, that is related to the lateral save and situations of maximum intensity in which the goalkeeper performs a parry or a fly. During a match-play, goalkeepers can performed up to a maximum of 17 dives (6.2 ± 2.7) before a technical action (De Baranda et al., 2008). Diving motion was analysed in four goalkeepers and it was found that the more skilled players dived faster (4 $m.s^{-1}$ as opposed to 3 $m.s^{-1}$) and more directly to the ball (Suzuki et al., 1987). The kinetic and kinematic characteristics of goalkeeper making diving saves showed that asymmetries exist in the movement patterns of goalkeepers according to the preferred or non-preferred side due to over rotational differences in the transverse plane (Spratford et al., 2009).

Hardly any information regarding goalkeeper-specific skills can be found with the exception of a recent study designed to assess specific defensive agility among thirty-four German goalkeepers aged 14–19 years (Knoop et al., 2013). Although the proposed protocol have successfully differenced the first goalkeepers and their substitutes, the instrumental apparatus is not easily accessible to coaches and trainers. Therefore, simpler protocols are needed to evaluate the particular technical skills involved in goalkeeping.

The overall purpose of the current research was to develop and evaluate two soccer-specific tests designed to examine goalkeeper-specific technique. To accomplish this purpose, the study was divided in two parts: 1) part one consisted in the evaluation of the reproducibility of two goalkeeper-specific tests; 2) and part two involved the examination of the construct validity of the applied tests. The assessment included measures of test-retest reliability. Validity was assessed by comparing two groups of young soccer goalkeepers of different competitive levels, hypothesizing that elite goalkeepers would perform better.

5.1.3 Methods

Participants and procedures

A total sample of sixty-six young male goalkeepers, all Caucasians, participated in the current research (Table 5.1). In the first part of this study, twenty-six goalkeepers (chronological age: 14.49 ± 2.52 years; accumulated soccer training: 5.62 ± 2.42 years; weekly volume of training: 5.8 ± 1.6 hours) completed the goalkeeper-specific tests on two separate occasions to determine test-retest reliability, with a week of interval between tests. In the second part, a subsample of eighteen elite goalkeepers (chronological age: 13.81 ± 1.81 years; accumulated soccer training: 6.00 ± 1.82 years; weekly volume of training: 6.1 ± 1.5 hours) and twenty-two non-elite goalkeepers (chronological age: 15.04 ± 1.43 years; accumulated soccer training: 6.64 ± 2.44 years; weekly volume of training: 5.8 ± 1.3 hours) was used to examine the construct validity. Elite goalkeepers belonged to the youth department of two professional clubs and played at a national level, while non-elite players were part of amateur clubs and competed at a regional level. Chronological age (CA) was calculated to the nearest 0.01 year by subtracting birth date from date of testing. Soccer experience, i.e. accumulated soccer training, and number of hours per week devoted to soccer training and preferred diving side were obtained by interview. None of the subjects reported recent injuries.

Clubs and coaches were contacted and fully informed about the nature of the study and the procedures involving data recording. All subjects received a complete explanation about the testing procedures and that they could withdraw from the study at any time before giving their verbal consent to participate. The study received ethical approval from the Scientific Committee of the University of Coimbra taking into account the standards for sports medicine and the recommendations of the Declaration of Helsinki.

The selection of the tests was based in the incorporation of sequences of movements to assess goalkeeper-specific technique in order to better resemble a game situation. Therefore, an acceptable ecological validity can be assumed. Besides, due to their simplicity and a minimum of required equipment, testing procedures were designed to be easily available to coaches and trainers. The final version of the applied tests resulted from an original straight sprint and diving protocol. Later, a change of direction previous to the diving action was added, before which the goalkeeper was asked to accelerate and decelerate until a full stop. Only then the proposed tests have emerged to assess goalkeeper-specific diving technique. All these adaptations occurred during three experimental sessions with an independent sample of six goalkeepers.

All field protocols were performed between 15:30 and 19:30 hours, on artificial grass with the players equipped with appropriate goalkeeper wear and soccer boots. A standardized warm up consisting in a total of 10 minutes, including jogging, a series of increasing intensity sprints, dynamic stretching and ball skills was performed before assessment. No static stretching exercises were allowed before any test (Fletcher and Monte-Colombo, 2010). Afterwards, a familiarization try-out preceded the two trials. Each subject was instructed and verbally encouraged to give their maximal effort during all tests. The subjects had 2 or more minutes of rest between 2 consecutive trials. Experimental conditions were controlled for air temperature (14 – 23ºC) and relative humidity (30 – 67%).

Table 5.1. Descriptive statistics for the total sample.

	n	Range		Mean			Standard deviation
		Minimum	Maximum	Value	SE	(95% CI)	
Chronological age (years)	66	10.92	18.57	14.49	0.25	(13.99 to 14.99)	2.04
Accumulated soccer training (years)	66	1.00	11.00	6.06	0.28	(5.50 to 6.62)	2.29
Weekly volume of training (h)	66	3.0	12.0	5.9	0.2	(5.6 to 6.3)	1.5
5-m sprint (s)	66	1.04	1.45	1.22	0.01	(1.20 to 1.25)	0.10
10-m sprint (s)	66	1.82	2.53	2.07	0.02	(2.03 to 2.12)	0.17
CMJ (cm)	60	17.85	46.10	30.63	0.87	(28.89 to 32.38)	6.76
CMJ-free arms (cm)	60	18.45	52.25	36.58	0.97	(34.63 to 38.52)	7.53
S-Keeper							
Right (s)	66	1.79	2.76	2.11	0.03	(2.06 to 2.17)	0.21
Left (s)	66	1.81	2.74	2.10	0.02	(2.05 to 2.14)	0.19
LS-Keeper							
Right (s)	66	3.91	5.88	4.72	0.06	(4.60 to 4.83)	0.48
Left (s)	66	4.07	5.76	4.72	0.06	(4.60 to 4.83)	0.45

Short-term muscle power

The subjects performed two vertical jump protocols. The first jump test consisted in the standardized counter movement jump (CMJ) during which the subjects were asked to keep their hands in their hips, to maintain their body vertical throughout the jump, and to land with their knees fully extended. The second vertical jump test was a free counter movement, jump during which the players freely swing the arms (CMJ-free arms). The vertical jump performances were evaluated by means of an optical acquisition system (Optojump, Microgate, Bolzano, Italy), developed to measure with 10-3-second precision all flying and ground contact times. The Optojump photocells are placed at 6 mm from the ground and are triggered by the feet of the subject at the instant of take-off and are stopped at the instant of contact on landing. Then calculations of the height of the jump were made (Komi and Bosco, 1978). The best of two trials was retained.

Acceleration was evaluated using two sprint tests, involving straight sprinting of 5-m and 10-m as fast as possible from a standing start position. Time was recorded using a system of dual infrared reflex photoelectric cells (Polifemo; Microgate). Players began from a standing start, with the front foot 0.5 m from the first timing gate. The best of two trials was retained.

Sprint-Keeper Test

The first protocol was proposed to examine diving technique, involving moving as fast as possible in the direction of a stationary ball after performing a change of direction, in a total distance of approximately 10 m. The Sprint-Keeper Test (S-Keeper) consists in: a) accelerating from a static standing position; b) straight sprint of 3 m; c) turn the cone while performing a change of direction and finally d) diving save action on the stationary ball. The subject who failed to catch the ball with both hands had to repeat the test. Two electronic timing gates (Polifemo; Microgate) were set up with the first gate at the goal line (0 m), and the second gate 7 m to the side at a 45º angle to the marked cone, placed 3 m in front of the starting point, according to the schematic representation in Figure 5.1 – panel A. The first pair of the electronic timing system sensors mounted on tripods was set approximately 75 cm above the floor and positioned 4 m apart, while the last pair was set approximately 10 cm above the floor. The ball centre was placed at a distance of 11 cm from the beam and at 8 m from the end line. S-Keeper performance was assessed for both sides and two trials were completed for each side. The best of each trial was retained.

Lateral Shuffle-Keeper Test

A second protocol was proposed to assess the diving technique, involving three changes of direction and two forms of displacement: frontward and lateral shuffle, in a total distance of approximately 11 m. The Lateral Shuffle-Keeper Test (LS-Keeper) consists in: a) accelerating from a standing position; b) straight sprint to cone A (placed 3 m in front of the starting point); c) facing forward and without crossing feet, lateral shuffle to cone B (2 m) and then back to cone A, always giving the inside to cones; d) diving save action on the stationary ball. The subject who crossed one foot in front of the other or failed to catch the ball with both hands had to repeat the test. Two electronic timing gates (Polifemo; Microgate) were set up with the first gate at the goal line (0 m) and the second moving 2 m to the side from cone A (placed 3 m in front of the starting point) and 5 m to the front, as shown in Figure 5.1 – panel B. The first pair of the electronic timing system sensors mounted on tripods was set on the goal line approximately 75 cm above the floor and positioned 4 m apart, while the second pair was set approximately 10 cm above the floor. The ball centre was placed at a distance of 11 cm from the beam and at 8 m from the end line. LS-Keeper performance was assessed for both sides and two trials were completed for each side. The best of each trial was retained.

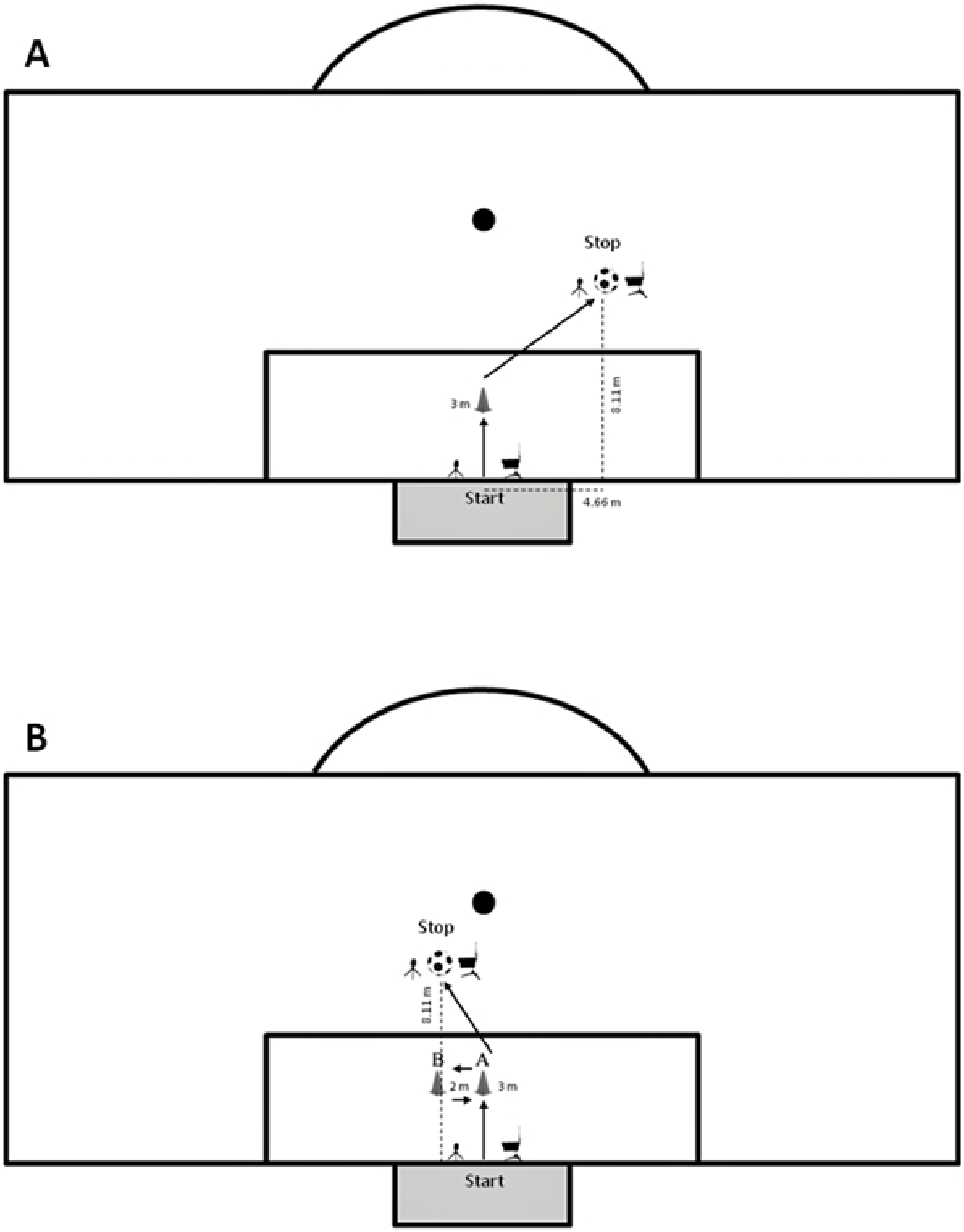

Figure 5.1. Schematic representations of the (A) Sprint-Keeper Test, and the (B) Lateral Shuffle-Keeper Test.

Statistical Analyses

Descriptive statistics for CA, accumulated soccer training, weekly volume of training, acceleration, vertical jump and goalkeeper-specific technique were calculated for the total sample. Reliability refers to the reproducibility of a measure or variable in repeated trials on the same subjects (Hopkins, 2000). Systematic bias between repeated measures was assessed using the paired samples T-test and effect sizes estimated (Rosnow and Rosenthal, 1996). A selection of statistical methods was completed to assess random error. Relative reliability was determined using Pearson's coefficients of correlation (r), reliability coefficients (R) (Mueller and Martorell, 1988), and intra-class correlation coefficient (ICC). Absolute reliability was determined using technical error of measurement (TEM) and coefficients of variation (%CV). The Bland-Altman procedures (Bland and Altman, 1986) were also conducted to determine limits of agreement between sessions. Limits of agreement can be seen as tolerance intervals, and represent the test-retest differences for 95% of a population (Atkinson and Nevill, 1998). Pearson correlations between the means and differences of two trial sessions with accumulated soccer training, weekly volume of training, acceleration, vertical jump and goalkeeper-specific technique were calculated for both protocols according to diving side, after controlling for CA.

Construct validity refers to the degree in which a protocol measures an hypothetical construct and it can be measured by comparing two different groups of subjects with different abilities (Currell and Jeukendrup, 2008). So, comparisons between elite and non-elite goalkeepers were performed after controlling for CA. Coefficients were interpreted as follows: trivial ($r < 0.1$), small ($0.1 < r < 0.3$), moderate ($0.3 < r < 0.5$), large ($0.5 < r < 0.7$), very large ($0.7 < r < 0.9$), nearly perfect ($r > 0.9$) and perfect ($r = 1$) (Hopkins et al., 2009). The smallest worthwhile difference (SWD) was determined using the Cohen's d effect size, representing the magnitude of improvement in a variable as a function of the between-subject standard deviation (SWD = 0.2 x between-subject standard deviation of young elite and non-elite goalkeepers) (Impellizzeri et al., 2008, Impellizzeri and Marcora, 2009). The true effect was considered unclear whenever the chance of benefit and harm were both ≥5%. Magnitude-based inferences about effects were qualitatively determined by the following thresholds: <0.5%: most unlikely; 0.5–5%: very unlikely; 5–25%: unlikely; 25–75%: possibly; 75–95%: likely, 95–99.5%: very likely; >99.5%: most likely

(Hopkins et al., 2009). Statistical significance was set at $p < 0.05$ and all analyses were carried out using the Statistical Package for the Social Sciences for Windows (SPSS v.22.0, Chicago, IL, USA).

5.1.4. Results

Mean results between the two trial sessions were similar for both tests when executed to the left side (Table 5.2). However, repeated measures for S-Keeper and LS-Keeper were significantly lower in the second trial session when performed to the right side (p = 0.010; p = 0.000). These differences were considered to be moderate (ES = 0.489) and large (ES = 0.630), respectively.

Reliability statistics for the goalkeeper-specific tests are presented in Table 5.3 and the Bland-Altman plots illustrated in Figure 5.2. Bivariate correlations between repeated measures of S-Keeper (r = 0.883; r = 0.876) and LS-Keeper (r = 0.912; r = 0.835) were high and significant. Test-retest analyses are quite similar for the protocols and side variation: S-Keeper right (TEM = 0.09; R = 0.90; ICC = 0.937; LOA = -0.28 to 0.16), S-Keeper left (TEM = 0.09; R = 0.89; ICC = 0.922; LOA = -0.23 to 0.29), LS-Keeper right (TEM = 0.19; R = 0.90; ICC = 0.950; LOA = -0.58 to 0.24) and LS-Keeper left (TEM = 0.20; R = 0.88; ICC = 0.908; LOA = -0.61 to 0.47). Data also indicated a within-subject variance of 4.18%, 4.37%, 3.97% and 4.16%, respectively for test protocol and side.

Mean performance and differences between repeated measures in goalkeeper-specific tests were verified according to diving side in Table 5.4. A weak to strong association with acceleration was presented. Also, a weak correlation was generally noted between accumulated soccer training and the means and differences of two trial sessions, particularly when performed for the left side. Interestingly, no linear association was found between goalkeeper-specific tests and vertical jump.

Table 5.2. Mean and standard deviation (SD) at each trial session, mean differences between tests and respective 95% confidence intervals and results of paired T-Test (n = 26).

	Session 1		Session 2		Mean difference		*t*	df	*p*	ES
	Mean	SD	Mean	SD	Value	(95% CI)				
S-Keeper										
Right (s)	2.19	0.24	2.13	0.23	0.06	(0.02 to 0.11)	2.801	25	0.010	0.489
Left (s)	2.13	0.22	2.16	0.27	-0.03	(-0.08 to 0.02)	-1.152	25	0.260	0.225
LS-Keeper										
Right (s)	4.81	0.51	4.64	0.45	0.17	(0.08 to 0.25)	4.059	25	0.000	0.630
Left (s)	4.77	0.45	4.70	0.49	0.07	(-0.04 to 0.18)	1.313	25	0.201	0.254

Table 5.3. Correlations between trial sessions, technical error of measurement (TEM), coefficient of reliability (R), coefficient of variation (%CV) and intra-class correlation coefficient (ICC) (n = 26).

	Coefficient of correlation			Reliability			ICC	
	r	(95% CI)	*p*	TEM	R	%CV	Value	(95% CI)
S-Keeper								
Right (s)	0.883	(0.796 to 0.959)	0.000	0.09	0.90	4.18	0.937	(0.860 to 0.972)
Left (s)	0.876	(0.801 to 0.959)	0.000	0.09	0.89	4.37	0.922	(0.826 to 0.96)
LS-Keeper								
Right (s)	0.912	(0.828 to 0.967)	0.000	0.19	0.90	3.97	0.950	(0.888 to 0.977)
Left (s)	0.835	(0.587 to 0.967)	0.000	0.20	0.88	4.16	0.908	(0.795 to 0.959)

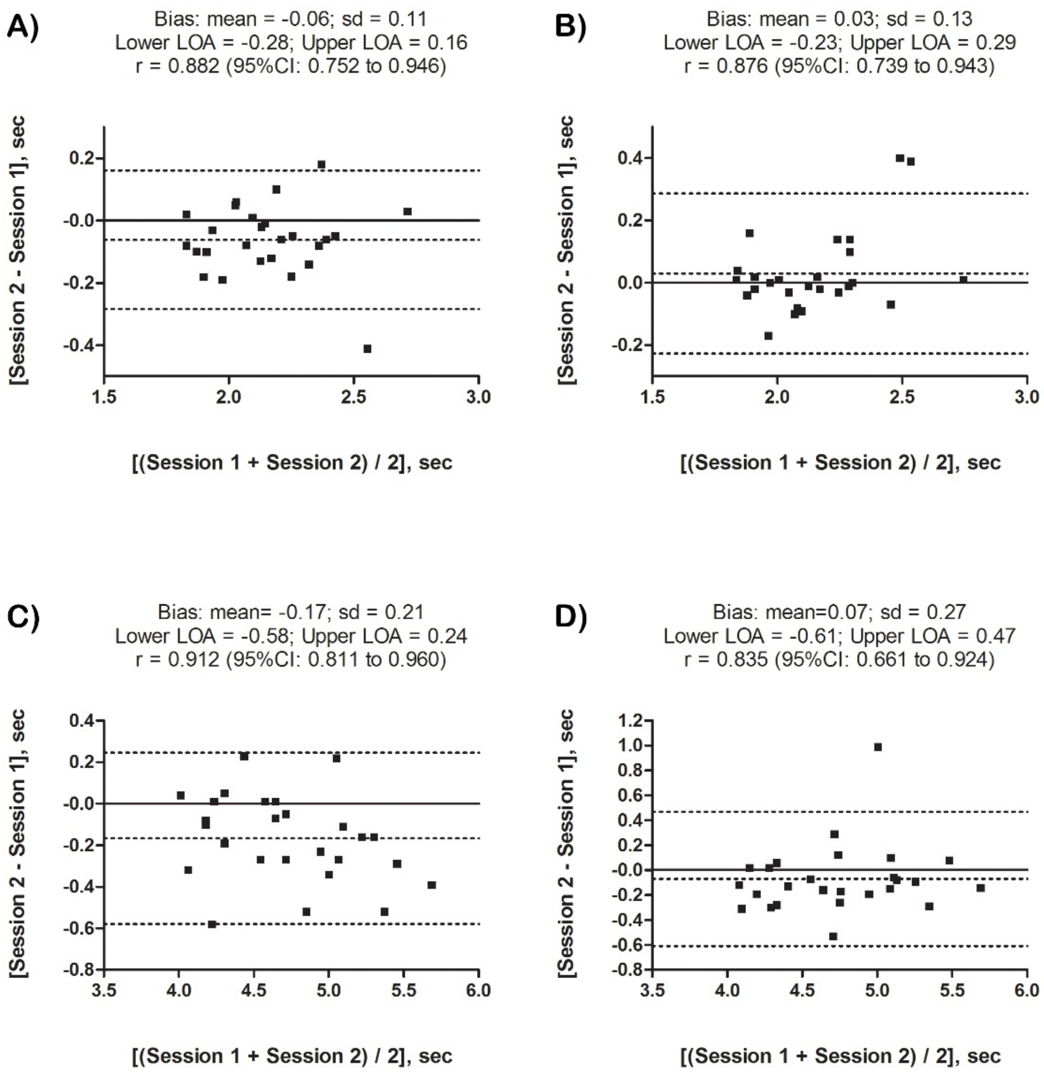

Figure 5.2. Analysis of Bland-Altman plot of the goalkeeper-specific tests: panel a) S-Keeper right; b) S-Keeper left; c) LS-Keeper right; d) LS-Keeper left. Mean, standard deviation bias, upper and lower limits of agreement are also presented.

When adjusted for the cofounder factor (CA), elite goalkeepers were estimated to perform better in all variables and to present lower asymmetries (Table 5.5). Multivariate analysis of covariance noted a significant effect of competitive level for the left side in both protocols (F = 6.111, p = 0.018; F = 5.322, p = 0.027). Nevertheless, small differences were observed among goalkeepers in the S-Keeper (d = 0.287; d = 0.219), while competitive level had a trivial (d = 0.057) and moderate (d = 0.329) effect in the LS-Keeper. The adjusted mean differences were respectively 0.024 s and 0.114 0073, resulting in unclear to most likely trivial probabilities that reflect the uncertainty in the true value. The critical values in the LS-Keeper were 0.005 s (~0.11%) and 0.029 s (~0.62%), after adjusted mean differences 0.136 s and 0.313 s were estimated, reflecting likely to most likely trivial chances of substantial differences between elite and non-elite goalkeepers.

5.1.5. Discussion

The present research evaluated the reproducibility and validity of two new goalkeeper-specific tests: the S-Keeper and the LS-Keeper. The main findings indicated a high correlation between trial sessions, and high relative reliability for the applied tests (i.e. coefficient of reliability and ICC). Comparisons with existent information on goalkeeper-specific assessment (Knoop et al., 2013) revealed higher values for ICC in our study and generally larger bias. The absolute reliability statistics suggested relatively little within-subject variation and fall within the general recommendations regarding coefficients of variation (<5%) in time trial protocols (Currell and Jeukendrup, 2008). Unlike previous research (Knoop et al., 2013), the mean and difference of two trial sessions in the S-Keeper and LS-Keeper had a stronger association to acceleration than to vertical jump. These differences can be partially explained by the physical nature of the Reaction and Action Speed tests, where subjects were instructed to react upon an optic signal by deflecting a ball placed in one of the four angles of the goal, as opposed to our study where goalkeepers were instructed to dive to a stationary ball. A stronger relationship between diving to low balls and horizontal jump or lateral jump can be expected.

Table 5.4. Partial correlations between the means and the differences of two trial session in the goalkeeper-specific tests with soccer experience, weekly volume of training and short-term muscle power, after controlling for chronological age (n = 26).

(X_i: variables)	Right				Left			
	Y1: Mean		Y2: Difference		Y1: Mean		Y2: Difference	
	$r_{(xi,y1)}$	(95% CI)	$r_{(xi,y2)}$	(95% CI)	$r_{(xi,y3)}$	(95% CI)	$r_{(xi,y4)}$	(95% CI)
S-Keeper								
X_1: Accumulated soccer training	0.127	(-0.286 to 0.440)	0.466	(0.194 to 0.716)	0.417	(0.109 to 0.691)	0.432	(0.093 to 0.703)
X_2: Weekly volume of training	-0.086	(-0.393 to 0.272)	-0.013	(-0.387 to 0.377)	-0.108	(-0.409 to 0.176)	0.164	(-0.126 to 0.412)
X_3: 5-m sprint	0.503	(0.163 to 746)	0.143	(-0.238 to 0.491)	0.647	(-0.357 to 0.834)	0.380	(0.004 to 0.744)
X_4: 10-m sprint	0.596	(0.162 to 0.838)	0.054	(-0.318 to 0.438)	0.798	(-0.513 to 0.918)	0.412	(0.032 to 0.827)
X_5: CMJ	-0.189	(-0.629 to 0.373)	-0.034	(-0.428 to 0.376)	-0.214	(-0.588 to 0.315)	-0.064	(-0.379 to 0.276)
X_6: CMJ-free arms	-0.316	(-0.705 to 0.249)	0.002	(-0.334 to 0.341)	-0.267	(-0.631 to 0.316)	-0.007	(-0.331 to 0.333)
LS-Keeper								
X_1: Accumulated soccer training	0.100	(-0.267 to 0.435)	-0.027	(-0.331 to 0.252)	0.083	(-0.274 to 0.399)	0.339	(-0.084 to 0.616)
X_2: Weekly volume of training	-0.051	(-0.494 to 0.350)	-0.082	(-0.528 to 0.348)	-0.113	(-0.495 to 0.267)	0.103	(-0.095 to 0.428)
X_3: 5-m sprint	0.302	(-0.114 to 0.651)	0.161	(-0.305 to 0.514)	0.245	(-0.199 to 0.606)	0.310	(0.094 to 0.662)
X_4: 10-m sprint	0.439	(-0.001 to 0.729)	0.071	(-0.393 to 0.445)	0.403	(-0.039 to 0.716)	0.290	(0.064 to 0.677)
X_5: CMJ	-0.136	(-0.537 to 0.362)	0.063	(-0.450 to 0.485)	-0.143	(-0.540 to 0.362)	-0.058	(-0.580 to 0.345)
X_6: CMJ-free arms	-0.195	(-0.556 to 0.337)	0.174	(-0.314 to 0.567)	-0.212	(-0.596 to 0.331)	0.093	(-0.455 to 0.460)

Table 5.5. Mean, adjusted mean controlling for chronological age, results of ANCOVA, effect size, chances of benefit, trivial and harmful for differences and qualitative inference between elite (n = 18) and non-elite (n = 22) goalkeepers.

	Elite			Non-elite			ANCOVA		ES	Magnitude	SWD (%)	% Chances B / T / H	Qualitative inference
	Mean±sd	Adjusted mean	SE	Mean±sd	Adjusted mean	SE	F	*p*					
S-Keeper													
Right (s)	2.10±0.18	2.054	0.038	2.04±0.19	2.078	0.034	0.202	0.656	0.287	Small	0.011 (0.51%)	36.7 / 51.9 / 11.4	Unclear
Left (s)	2.06±0.16	2.013	0.33	2.09±0.18	2.127	0.030	6.111	0.018	0.219	Small	0.007 (0.35%)	0.2 / 99.8 / 0.0	Most likely trivial
LS-Keeper													
Right (s)	4.67±0.41	4.581	0.100	4.64±0.45	4.717	0.090	0.948	0.337	0.057	Trivial	0.005 (0.11%)	0.0 / 100.0 / 0.0	Most likely trivial
Left (s)	4.60±0.35	4.508	0.097	4.75±0.51	4.821	0.088	5.322	0.027	0.329	Moderate	0.029 (0.62%)	11.5 / 88.5 / 0.0	Likely trivial

ES = Cohens'd effect size; SWD = Smallest worthwhile difference; B / T / H = Beneficial / Trivial / Harmful.

The use of paired samples T-test was able to detect a systematic bias in both protocols. This tendency for performance in retest to be better than the prior test could suggest a general learning or fatigue effects of the tests (Atkinson and Nevill, 1998). However, it was only verified when goalkeepers dived to the right side, surprisingly the same side which 53.5% of the subjects claimed to be their preferred diving side, while 7.7% had no side preference. It is possible that goalkeepers increase their technical ability in the test performance according to side preference, being the results less dependent on acceleration and vertical jump. This means that they had an enhanced efficiency in the ability to throw the body as fast and further as possible in direction to the ball for their preferred side. The potential effect of diving direction in the movement patterns of elite goalkeepers have been previously investigated (Spratford et al., 2009). The number of relationships exhibited by the thorax, pelvis, and hip kinematics, peak joint moments and centre of mass indicated that the critical time period of the dive occurred at or before the initiation phase as greater lateral rotation of the pelvis and thorax was already evident at this point for the non-preferred side. It is therefore reasonable to think that measurement error between sessions might be more related to biological or mechanical variation, i.e. random error (Atkinson and Nevill, 1998).

Performance in diving saves is influenced by several components (e.g. acceleration, deceleration, jumping, change of direction, side preference and diving movement), resulting in a combination of physiological, metabolic, biomechanical and morphological components. For example, technical execution in changing of direction could be conditioned by CA and mastery level of subjects (Condello et al., 2013). In fact, the capability of an individual to complete a relative short ground contact time and generate force in short period of time, as well as leg power generated during stretch-shortening cycle, could be important factors in rapid changes of direction (Haj-Sassi et al., 2011, Young et al., 2002). In our study the dominant leg assessment was not considered but asymmetry between lower limbs has been shown to influence performance in single leg jumps (Sugiyama et al., 2014). A variety of training techniques is therefore required in order to optimize the overall performance in diving saves, particularly by enhancing the displacement previous to performing a technical action, the take-off movement and by reducing asymmetries between diving sides (Condello et al., 2013, Young et al., 2002, Mendez-Villanueva et al., 2011, Miyaguchi and Demura, 2010, Haj-Sassi et al., 2011).

In the second part of our study construct validity was assessed by comparing goalkeeper-specific technique in two different groups. After controlling for CA, elite goalkeepers performed significantly better to the left side in both protocols. Nevertheless, competitive level had a trivial to moderate effect on goalkeeper-specific technique. Like in the current study, differences were found in the Reaction and Action Speed tests among first and substitute goalkeepers, for the left side (Knoop et al., 2013). Authors presented a possible relationship between right-handed goalkeepers and movement characteristics when diving to the right corner, as they might be more self-confident, precise and generate more acceleration. A previous study suggested that skilled movements show a right-leg dominance in the take-off leg in jumping movements, although no marked lateral dominance was shown on isokinetic strength of lower limbs (Miyaguchi and Demura, 2010, le Gall et al., 2010). Though speculative, our results again suggested that asymmetries in diving side might be related to personal choices and accumulated soccer training or training volume, since 52.5% of this subsample claimed the right side to be their preferred, while 22.5% stated no side preference. Curiously, a right side dominance was also found in a qualitative evaluation of diving actions as most of the goalkeepers chose to fall over their right side (Schmitt et al., 2010).

Diving save is a technical behaviour that goalkeepers can perform according to the contextual dimension in the defensive moment (shooting, crossing, through ball and 1 vs 1), and while performance in skilful movements is one of the most important aspects in goalkeeping, the proposed tests tend to be physiological in nature (Currell and Jeukendrup, 2008). In this regard, the distinction between “skill” and “technique” has been highlighted (Ali, 2011). Skill involves the ability to select and perform efficient and effective movement patterns as determined by the contextual demands, whereas technique refers to the ability to bring about pre-determined results with good pattern of movements. Consequently, a higher discriminative validity should include more complex protocols, involving anticipatory perceptual-motor behaviours (Knoop et al., 2013, Savelsbergh et al., 2002), with the risk to increase random error.

For team sports, in which there is no clear relationship between test measures and actual competitive performance, the smallest worthwhile difference (0.2 of the between-participants standard deviation) represents a sport-specific value beyond which a difference is likely to be important to detect in practical terms (Hopkins, 2000, Currell and Jeukendrup, 2008). Looking at the overall performance of all the forty subjects

(Table 5.5), it would appear that goalkeepers who are perceived to possess superior goalkeeping abilities performed better in both protocols – high construct validity (Knoop et al., 2013). Nevertheless, it was possible to identify the SWD between elite and non-elite goalkeepers around 0.51 – 0.35% and 0.11 – 0.62%, respectively for both tests. We need to keep in mind the contribution of several components of the S-Keeper and LS-Keeper towards the overall performance. So, cautions must be advised when distinguishing goalkeepers based uniquely on the time to perform a predetermined technical skill.

The effectiveness of long-term training programs requires the goalkeeper to excel in a wide range of physical, technical and tactical behaviours, providing appropriate game-related stimulus on short-term muscle power and perceptual-cognitive skills. Although analytical forms might be appropriate to introduce and consolidate technical contents in the period before middle adolescence, as it seems to be optimal in the technical specialization (Rebelo-Goncalves et al., 2015), it is desirable that training methodologies emphasizes the development of goalkeeping skills, in a balanced combination with technical learning. The design of goalkeeper-specific activities must consider that successful goalkeeping actions during match-play are measured as an effective result of physical and technical responses in the minimal possible time. Goalkeepers should ultimately be prepared for anticipating the pathway and direction of the kicked ball (Lidor et al., 2012) and to produce effective actions in response to variation in visual information with the aim of decreasing movement time (Dicks et al., 2011).

5.1.6. Conclusion

The current research supports a better understanding regarding performance-related characterization of soccer goalkeepers through the development and evaluation of two new goalkeeper-specific tests: the S-Keeper and the LS-Keeper. Both protocols showed high reliability and presented sufficient validity when comparing goalkeepers by competitive level. Nevertheless, assessing diving technique through a predetermined action in direction to a static ball placed on the ground compromises an individual ability to respond to a game-related stimulus. Applied research should incorporate anticipatory perceptual-motor behaviours in order to achieve a better ecological validity of the actions performed by the goalkeepers (Savelsbergh et al., 2002, Lidor et al., 2012). Also, the potential influence of the variability associated to anthropometrical factors such as stature and the proportionality trunk/limbs was not considered in the present study. The assessment of diving technique can inform coaches and goalkeepers about good movement patterns, take-off movements and possible asymmetries between diving sides.

5.1.7. Acknowledgments

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5.1.8. Key points

- The S-Keeper and LS-Keeper are reliable tools to assess goalkeeper-specific technique, even though a systematic bias was verified when goalkeepers dived to the right side.
- The S-Keeper and LS-Keeper were also able to discriminate young goalkeepers by competitive level, particularly when performed to the left side after controlling for chronological age.
- The proposed tests are recommended as practical instruments to assess and provide relevant information about the influence of several components of performance in the overall execution of a diving save (e.g. previous displacement, movement patterns, take-off movements and possible asymmetries).

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Chapter 6

General Discussion and Conclusions

6. General discussion and conclusions

The current section presents the main findings of **Chapters 3**, **4** and **5**. The rationale behind this section is to summarize the main results and contributions of each one of the five studies in order to promote a better understanding regarding performance-related characterization of young soccer goalkeepers. Accordingly, this research project adopted a multidisciplinary approach to examine the specificity of performance characteristics in young male goalkeepers.

First, to study the anthropometric, physiological and skills profile of goalkeepers the following works have been carried out:

- **Study 1:** Rebelo-Gonçalves R, Coelho-e-Silva MJ, Tessitore A, Figueiredo AJ (2015). Anthropometric and Physiological Profiling of Youth Soccer Goalkeepers. *International Journal of Sports Physiology and Performance, 2015.* doi: 10.1123/ijspp.2014-0181;
- **Study 2:** Longitudinal Study of Aerobic Performance and Soccer-Specific Skills in Male Goalkeepers Aged 11–18 Years. *In Revision.*

Second, to examine the effect of competitive level in short-term maximal efforts among goalkeepers the following works have been produced:

- **Study 3 (Pilot Study):** Reproducibility of Estimated Peak Output in the Force-Velocity Test derived from multiple 10-s maximal sprints in the cycle-ergometer. *In Revision*;
- **Study 4:** Maximal Intensity Short-Term Performance in Soccer Goalkeepers: Variation by Competitive Level. *Submitted*.

Finally, one work was produced to develop and evaluate two new goalkeeper-specific tests:

- **Study 5:** Assessment of technical skills in young soccer goalkeepers: reliability and validity of two goalkeeper-specific tests. *In revision*.

This section also represents a reflection on the implications for future research. In addition, it aims to help coaches, trainers and administrators involved in youth soccer programs. To finish, a dynamic model for performance characteristics in goalkeeping is suggested.

6.1. Field-based performance characteristics of young soccer goalkeepers

Soccer can be a highly selective and specialized sport since young ages. It requires particular anthropometric and physiological characteristics for different playing positions. Specific-positional demands also includes technical, tactical and psychological skills (Coelho e Silva et al., 2010; Kannekens, Elferink-Gemser, & Visscher, 2011; Malina et al., 2005; D. Memmert, 2010). However, evidence regarding position-related variation among young soccer players often excludes the goalkeeper position or provides inconclusive results.

Results from **Study 1** were generally consistent with the hypothesis that goalkeepers differed from outfield players in body size, proportions, maturity, physiological parameters, soccer-specific skills and goal orientation. On the other hand, playing position could be reasonably predicted based on dribbling speed, shooting accuracy and passing tests, while fat-free mass and ball control respectively entered the model in middle and late adolescence.

Somewhat similar, a specific profile was already identifiable from a young age (8–10 years) (Deprez et al., 2015; Gil et al., 2014). Goalkeepers were generally taller, heavier and had bigger amount of fat components. In contrast to our results, maturity-related variation among soccer players of different playing positions was more evident in other studies. Goalkeepers and defenders, seemed to enter puberty earlier since their APHV occurred at a younger age than midfielders and attackers (Deprez et al., 2015). Medium to large effect sizes were detected between goalkeepers and outfield players for maturity offset, predicted mature height (184 cm *vs* 174 cm) and percentage of predicted mature height (Gil et al., 2014). Maturity status was also of particular relevance when distinguishing selected (186 cm) from non-selected goalkeepers (182 cm). Older players and those advanced in maturation tend to be larger in terms of body size and thus, to be stronger and more powerful (Figueiredo, Gonçalves, Coelho e Silva, & Malina, 2009; Malina, Eisenmann, Cumming, Ribeiro, & Aroso, 2004; Vaeyens et al., 2006). The higher weight-for-height ratio probably reflects a larger fat free mass, specifically muscle mass, in later adolescence, suggesting that body size variation is mostly related to growth and maturation. Consequently, identification and selection procedures for the goalkeeping position are heavily influenced by body size dimensions and biological maturity status. Moreover, body size is one of the most important requirements to reach professional goalkeeping (Boone, Vaeyens, Steyaert, Vanden Bossche, & Bourgois, 2012; Reilly, Bangsbo, & Franks, 2000).

Coaches seem to select a given player to a defensive or offensive position based on body size, but moderate differences between goalkeepers and outfield players were already observed for endurance, speed, combined speed and agility, and soccer-specific motor coordination from 8–10 years (Deprez et al., 2015; Gil et al., 2014). Interestingly, these differences were more pronounced among young Belgian participants in high-level soccer development program, consisting of four training sessions (one physical overload session, one strength session and two technical-tactical training sessions) and one game (on Saturday). Nevertheless, literature is only consistent for aerobic performance (Deprez et al., 2015; Gil, Gil, Ruiz, Irazusta, & Irazusta, 2007; Gil et al., 2014; Lago-Peñas, Casais, Dellal, Rey, & Dominguez, 2011; Wong, Chamari, Dellal, & Wisloff, 2009), reporting that goalkeepers are outperformed by defenders, midfielders and forwards, regardless the used protocol.

Other physiological characteristics, such as change of direction, speed and jumping, are usually seen as important parameters in later stages of goalkeeping (Knoop, Fernandez-Fernandez, & Ferrauti, 2013; le Gall, Carling, Williams, & Reilly, 2010; Rebelo et al., 2013), although goalkeepers tend to perform worse than players with other positional roles (Deprez et al., 2015; Gil et al., 2014). In other words, there are testing measures accurate enough to discriminate goalkeepers by competitive level, but not to distinguish goalkeepers from other players. These particular differences between goalkeepers and outfield players tend to disappear as they get older and goalkeepers reach the requirements to become professionals (Boone et al., 2012). Other possible explanation for the lack of consistency in the available information is that testing batteries are usually not appropriate to evaluate the goalkeepers' specificity. Goalkeeping usually involves multi-joint powerful movements and almost all the body's muscle groups are used. Thus, position-specific test measures should include other protocols such as agility upper limbs strength, flexibility (Deprez et al., 2015) and functional strength, as core muscles basically stabilize and generate powerful movements of the extremities.

Playing position-related variation was even impaired when soccer-specific tests were included. Differences were only found for the Hoff dribbling test (Wong et al., 2009) among U-14 players, and the Dribble ball test (Deprez et al., 2015)from U-9 to U-19 players. In **study 1** we noted that goalkeepers were outperformed by outfield players in dribbling speed and passing points (moderate to nearly perfect differences), while they had higher shooting accuracy. Nevertheless, goalkeepers' relation with the ball is an important feature in contemporary soccer, especially in later stages of their development (Rebelo et al., 2013). Goalkeepers are more and more required to participate in supporting actions with the defensive line (building up the attack and dealing with back passes), to be accurate in distribution, to control the opponents deep (through ball or act as a sweeper-keeper) and play outside the penalty area.

Study 5 proposed two specific field-based measures to examine goalkeepers' technique: the S-Keeper and the LS-Keeper. Both protocols showed high reliability and presented sufficient validity when comparing goalkeepers by competitive level. One might argue that assessing diving technique through a predetermined action in direction to a static ball placed on the ground does not replicate entirely what happens during a game and thus, compromising a goalkeepers ability to respond to a game-related stimulus. Althoughacceleration, vertical jump, horizontal jump and goalkeeper-specific technique are specific qualities and relatively unrelated, a possible relationship between horizontal jump and diving to low balls was verified, particularly in U-13 and U-17 (Rebelo-Gonçalves, Figueiredo, Valente-dos-Santos, Coelho-e-Silva, & Tessitore, 2015), whereas diving to the upper corners was related to vertical jump (Knoop et al., 2013). Performance in diving saves is influenced by several components (e.g. acceleration, deceleration, jumping, change of direction, side preference and diving movement), resulting in a combination of physiological, metabolic, biomechanical and morphological components that must be acknowledged and examined.Rather than applying maximal strength, goalkeeping actions are largely related to an optimal use of the available strength on a giving time/task.

Diving save is a technical behaviour that goalkeepers can perform according to the contextual dimension in the defensive moment (shooting, crossing, through ball and 1 *vs* 1), and while performance in skilful movements is one of the most important aspects in goalkeeping, the proposed tests tended to be physiological in nature (Currell & Jeukendrup, 2008). In this regard, and with serious implications for goalkeeper-specific training and testing, (Ali, 2011) clarifies two distinct concepts: "skill" involves the ability to select and perform efficient and effective movement patterns as determined by the contextual demands, whereas "technique" refers to the ability to bring about pre-determined results with good pattern of movements. Consequently, a higher discriminative validity of a testing measure should include more complex protocols, involving anticipatory perceptual-motor behaviours (Knoop et al., 2013; G. J. Savelsbergh, Williams, Van der Kamp, & Ward, 2002), with the risk to increase random error. Additionally, by adopting analytical forms of training (i.e., isolated technical training), techniques cannot be related to a situation. It is important that children experience in which situations or constraints they have to use which technique (Daniel Memmert, 2015). Only then they will be able to apply those techniques in real complex forms or a formal way of soccer match. The specific nature of goalkeeping demands during practice calls for balanced training methodologies, where analytical and global forms of training are adopted.

Although the awareness of effective training programs for goalkeepers is growing, a common question for those involved in youth soccer coaching is: *"when should a player be specialized in the goalkeeping position and/or receive goalkeeper-specific training"*? According to the results observed in **Study 1**, the period before middle adolescence seems to be optimal for technical specialization. Actually it was possible to correctly classify the playing position based on fat-free mass and three manipulative skills in younger players (11–15 years of age), suggesting that differences between goalkeepers and outfield players can be established during childhood. A study carried out with a Belgian sample of youth soccer players identified a differentiable profile since the U-9 age group (Deprez et al., 2015). From a global structural level to a more operational local level, soccer associations, clubs and coaches should consider long-term training programs and methodologies from childhood and early adolescence, focusing on age-appropriate psychological, physical and technical-tactical contents.

The limited results of longitudinal studies suggest the need for normative data across adolescence for youth players by playing position (Huijgen, Elferink-Gemser, Post, & Visscher, 2010; Valente-Dos-Santos et al., 2014); such data are potentially valuable for screening and monitoring development among subjects. Still, hardly any longitudinal information exists considering the goalkeeping position. In **Study 2** recognized variables by their discriminatory power by playing position (Gil et al., 2007; Lago-Peñas et al., 2011) and competitive level (Rebelo et al., 2013) among youth soccer players were included. A specific developmental model to predict longitudinal changes in aerobic performance and soccer-specific skills was constructed based on a Portuguese sample of 16 goalkeepers aged 11–18 years, in a total of 71 measurements. Annual volume of training was an important contributor to explain variance in dribbling speed and passing skills, while chronological age (CA) was a consistent source of variation in all performance indicators. Based on the multilevel models, one year predicts improvements in the performance scores of 0.35 s, 1 point and 192.5 m, correspondingly. However, CA (per se) may not be a sufficiently sensitive indicator, and it can limit our understanding of the developmental changes in performance since training experience proportionally follows CA.

The significant contribution of the amount of training to dribbling performance was previously recognized among outfield soccer players (Huijgen et al., 2010; Valente-Dos-Santos et al., 2014). Goalkeepers' are usually involved in specific training-related activities. Thus, in order to obtain a clearer understanding about developmental changes in performance characteristics in soccer goalkeepers, a more complete description and quantification of these activities (e.g., goalkeeping-specific, integrated, strength and conditioning) is necessary. Besides, we need to keep in mind the transient nature of an individual's "readiness" or aptitude, when assessing multidisciplinary performance characteristics in youth soccer. In other words, the time and tempo of development of a given characteristic varies between subjects. For instance, the development of aerobic performance in elite youth soccer was related to growth and body size, with an additional contribution of motor coordination (Deprez et al., 2014). In another example, height growth of 1 cm predicts 1.927 s of improvements in dribbling speed (Valente-Dos-Santos et al., 2014), and the most rapid improvements were verified from 12 to 14 years, continuing to improve further after the age of 16 (Huijgen et al., 2010). Lastly, the time to complete the Loughborough Soccer Passing Test improved over the years (18%), while the skill performance time improved to an even greater extent (32%) (Huijgen, Elferink-Gemser, Ali, & Visscher, 2013).

The identification of different rates of learning and possible influences on performance parameters should be acknowledged by all agents involved in youth sports. Furthermore, this developmental process occurs naturally as a sport evolves (e.g., tactical and technical requirements imposed by regulatory changes). Performance enhancement will emerge while talented individuals add new skills or solutions as they engage with different forms of practice. Basically, players need to demonstrate an ability to adapt to the strategies arising from contextual aspects (i.e., training and competitive). The singularity of these aspects results in a multi-pathway to expertise that coaches and sport and exercise scientists must consider in relation to goalkeeping performance.

6.2. Laboratory-based performance characteristics of young soccer goalkeepers

High-level soccer is characterized by a substantial number of high-intensity exercise bouts. During a match-play, each players performs an average of 1000–1400 short-term actions, based on sprints of 2–4 s repeated at every 90 s (Stolen, Chamari, Castagna, & Wisloff, 2005), more than 700 turns (Bloomfield, Polman, & O'Donoghue, 2007) and 30 to 40 tackles and jumps (Bangsbo & Andersen, 2013). High-intensity actions are even of greater importance when dealing with goalkeeping behaviors. The average number of high speed actions was 10±6, with a total range between 0 and 40, while in just 2% of the time the goalkeepers were moving at high-intensity (Di Salvo, Benito, Calderon, Di Salvo, & Pigozzi, 2008).

The physiological profile generated from laboratory-based testing have some value in allowing intra and inter-individuals comparisons. The use of normative ranges, as well as the identification of a players' weaknesses and strengths, may be used for training prescription and monitoring adaptations and changes. Important proprieties of maximal intensity short-term protocols are recommended in Figure 6.1 when testing laboratory-based performance in soccer players.

Even though the Wingate Anaerobic Test (WAnT) has shown to be a highly valid and reliable tool for assessing the maximal anaerobic power (peak and mean) and anaerobic fatigue (Bar-Or, 1987), one of the major limitations is that force of external resistance might not satisfy the muscle-force velocity relationship, particularly in youth populations and athletes. Moreover, during a 30 s WAnT, the energy contribution of the ATP-PC pathway is 28%, of the glycolytic pathway is 56%, and of the aerobic pathway is only 16% (Smith & Hill, 1991). An alternative to the WAnT protocol is provided by a series of all-out sprints against a range of braking forces: the Force-velocity test (FVT).

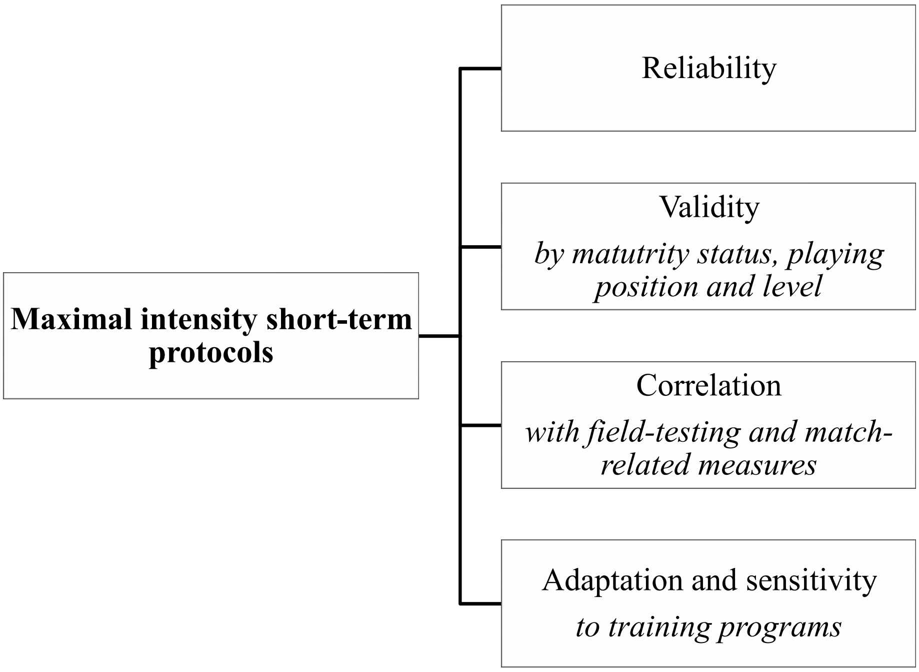

Figure 6.1. Factors to consider in the selection of laboratory-based maximal intensity short-term protocols in soccer players.

Study 3 was conducted as a pilot study where we've examined the reproducibility of estimated peak output and estimated pedal velocity in 22 physical education students, using a FVT. The cycling test involved a set of 3 to 5 maximal bouts of 10 s trials against a range of braking forces. Test-retest results showed good reliability for the investigated measures (TEM = 31.9 W, %CV = 3.5, ICC = 0.986; TEM = 5.4 rpm, %CV = 3.8, ICC = 0.924). For this reason, the 10 s FVT protocol was included in **Study 4**, with the aim to compare maximal intensity short-term performance in 33 young male soccer players of contrasting levels. Another reason was that the use of a fixed applied force of 0.075 $kg\cdot kg^{-1}$ may not be optimal for eliciting anaerobic peak power outputs in cycle-ergometer tests. This common braking force tended to underestimate peak power in young soccer goalkeepers after examining the agreement between peak power outputs derived from the WAnT and the FVT (Rebelo-Gonçalves et al., 2014). The mean difference between peak power outputs was significant (mean difference=80.7 W, 95% CI: 45.0 to 116.5, $t_{(32)}$=4.598; p<0.001).

Results from **Study 4** revealed a superior performance of goalkeepers competing at a national level in cycle-ergometry and isokinetic strength. Moderate differences were found in several WAnT measures (mean output, explosiveness and pedal velocity), suggesting that data provided by the WAnT can still be valuable for coaches and practitioners, as well as to provide predictive and normative values on cycle-ergometry. On the other hand, the 10 s FVT protocol might not be so suitable to assess young soccer goalkeepers, unless we intend to evaluate peak output with greater accuracy. Although goalkeepers displayed the highest values for peak power when compared to outfield positions, significant differences were only found for mean power relative to body mass and fatigue index (Nikolaidis, 2014). The linear combination of training experience, ratio knee flexors to knee extensors at $180^{o}\cdot s^{-1}$ and pedal velocity in the 30 s all out cycling exercise was able to correctly predict 87.9% of goalkeepers into the original groups. Peak concentric torque of knee flexors in the preferred and non-preferred leg at $240.2^{o}\cdot s^{-1}$ differed significantly between goalkeepers who ultimately joined professional clubs and those who remained amateurs (le Gall et al., 2010).

The knee flexors muscle group act eccentrically during ball kicking, running or sprinting, by generating tension while lengthening to decelerate knee extension. Furthermore, it seems that strength in knee flexors play an important role in goalkeeping and a systematic training is required to improve it as this muscle group is highly trainable (Mendiguchia et al., 2014). In this sense, the exposure to systematic training was again highlighted in our research. Considering that, up to now, goalkeeper-specific training is not systematically available in all long-term training programs, it can be assumed that goalkeepers demonstrating superior performances were exposed to systematic training sessions more suited to their positional demands, developing and optimizing their individual potential as goalkeepers.

6.3. Directions for future research

Throughout the **Chapters 3**, **4** and **5** specific limitations have been pointed out. Nevertheless, the current section assumes a prospective analysis of the collective work presented in this doctoral thesis, allowing that future research can be developed. Goalkeeping has been very much under-researched from an academic and applied point of view, and a multidisciplinary study of basic performance characteristics in soccer goalkeepers is still lacking. One of the main reasons for the low interest regarding this highly selected and specialized group, is the low ratio of goalkeepers per team (usually 2-3:24), resulting in bias of mean values. Sample size in most of our studies was limited to a wide age-range and maturity status.

The cross-sectional and longitudinal profiling of young soccer goalkeepers in **Chapter 3** considered anthropometric and physiological characteristics, biological maturation, psychological and soccer-specific skills. In this regard, a lot was left undone in the psychological domain since only the TEOSQ was used to assess goal orientation. Recent evidence supports the importance of cognitive functions (Verburgh, Scherder, van Lange, & Oosterlaan, 2014), self-regulatory skills (Jonker, Elferink-Gemser, Toering, Lyons, & Visscher, 2010), and emotional intelligence (Laborde, Dosseville, & Allen, 2015) for sports performance. Despite soccer is a team sport, goalkeeper performance is highly individualistic as it has specific requirements, with strong psychological skills associated. Particular aspects like focus, self-confidence, dealing with errors and pressure, motivation, discipline and leadership can have a significant impact on goalkeeping performance and it would be of particular interest to investigate.

Another shortcoming of **Chapter 3** relates to the absence of possible relevant measures in goalkeeping performance such as arm spam, upper limbs strength (Deprez et al., 2015; Gil et al., 2014), flexibility, core strength and coordination (Vandendriessche et al., 2012). Motor coordination skills in goalkeeping are expressed by spatio-temporal orientation, kinaesthetic differentiation, reaction, balance, rhythm and the ability to combine and transform movements. A particular example of the aforementioned, particularly at younger ages, is when dealing with crosses or high balls. The goalkeeper is required to predict the moment to intercept the ball according to its trajectory, the previous displacement and jumping ability, also considering the team-mates' and opponents' movements. Supplemental information provided by the results of a previous study (Dessing & Craig, 2010) showed that spin direction in curved free-kicks influenced the goalkeepers' movement, reflecting the limited sensitivity to visual acceleration of the human visual system.

In an attempt to overcome the lack of goalkeeper-specific measures, findings in **Chapter 5** suggested that the S-Keeper and the LS-Keeper are reliable and valid tools to assess goalkeeper-specific technique. Nevertheless, goalkeeper-specific assessment is still scarce in perceptual and cognitive aspects when responding to a specific stimulus. The ability of a player to predict what is likely to happen prior to an event occurring and to effectively select and execute an appropriate action in a given situation is a crucial aspect to expert performance in soccer (Roca, Williams, & Ford, 2012). Future research should incorporate the assessment of anticipation and decision making skills (Lidor, Ziv, & Gershon, 2012; G. Savelsbergh, van Gastel, & van Kampen, 2010; G. J. Savelsbergh et al., 2002).

The ecological validity of cycle-ergometry when assessing young soccer players (**Study 4**) might be questionable, particularly for the WAnT protocol. It has been suggested that a series of short efforts interspersed by brief recovery periods seems to mimic the activity pattern observed during a soccer match (Meckel, Machnai, & Eliakim, 2009). For this reason, a more suitable FVT protocol might be a promising alternative for investigation. We need also to consider that there is a predominance of concentric actions of the leg muscles in cycle-ergometer all-out testing, limiting the stretch-shortening muscle tension cycle (Sands et al., 2004), especially when this type of muscle action is so important in successful goalkeeping. The functional perspective suggested by our results in **Study 4** claim the need for eccentric evaluation in both the dominant and non-dominant legs. It would be interesting to examine the association between laboratory and field-based measurements in soccer goalkeepers, as well as to test the effects of specific training programs (interventional studies) in short-term maximal efforts.

Studies 1, **4** and **5**, we observed the variance in several performance characteristics according to playing position (Goalkeeper *vs* outfield players) and competitive level (national *vs* regional). Still, the answer to the question if these differences were due to disparity selection criteria for the position, exposure to systematic goalkeeping training, or some combination of both, remains unclear. Even the observed changes and predictors influencing aerobic performance and soccer-specific skills in **Study 2** need to be clarified since quantitative measures of training-related activities might not be sensitive enough (Valente-Dos-Santos et al., 2014). The interaction of training quality and performance characteristics in young soccer goalkeepers was overlooked. This means that we need to examine the behavioral interactions between youth and adults. We must go to the training grounds and observe the amount of practice devoted to goalkeeper-specific activities, integrated and strength and conditioning training, as well as to understand the physiological and technical loads associated with it.

While the use of wearable global positioning technology has been extensively used to measure a player position, velocity and movement patterns (Cummins, Orr, O'Connor, & West, 2013), micro technology sensors (i.e. accelerometers, gyroscopes and magnetometers) have the capability to detect sport-specific movements and to provide feedback on performance (Chambers, Gabbett, Cole, & Beard, 2015). The Catapult OptimEye G5 was specifically engineered to monitor and analyse the short and explosive movements involved in goalkeeping and that are not captured by GPS and video technologies. Utilising Inertial Movement Analysis (IMA), this device can break down repeated high intensity efforts, metabolic power, accelerations, decelerations, changes of direction (left and right) and jumps (height and frequency). The importance of this data for planning and monitoring practice drills can be valuable. Still and up to date, no data is available about the quantification of goalkeepers' workloads.

6.4. Dynamic model of performance characteristics in goalkeeping

The goalkeeper is soccer's outlier: an individual tasked performer within a team sport. Goalkeeping occurs in a fast-moving game of improvisation, constraints, spatio-temporal pattern recognition, decision making and effective skilful movements. However, applied research and goalkeeper-specific training are still lacking a theoretical framework, beyond the fragmented view of performance according to domains in which a player must excel (anthropometric, technical, tactical, physiological and psychological characteristics). It is essential to give a meaning to the available knowledge through a more holistic perspective of the goalkeeper and its individuality. Thus it is proposed a dynamic model of performance characteristics in soccer goalkeepers based on the acquisition of behavioural intentions and in the promotion of effective and competent actions in the game (Figure 6.2).

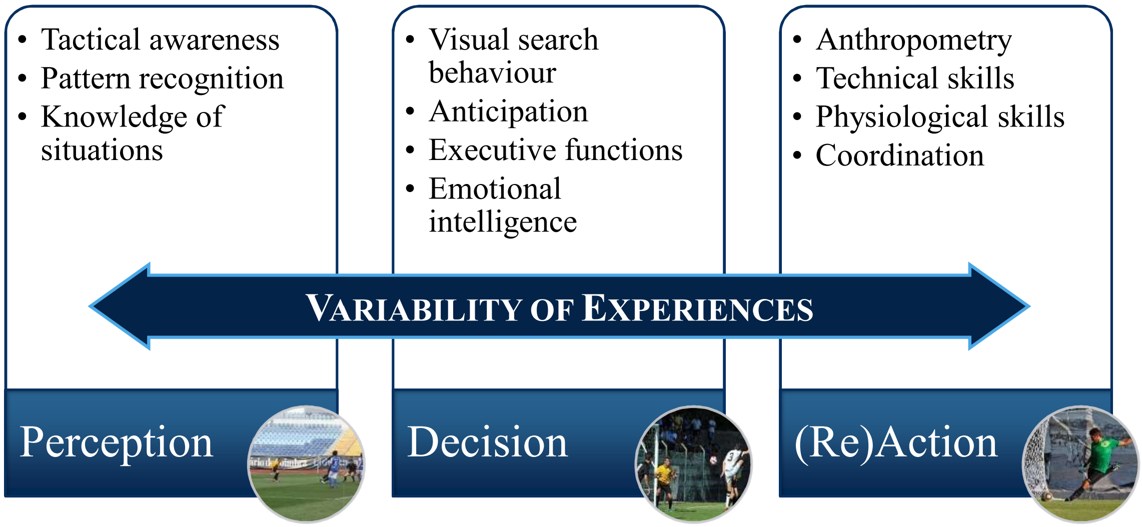

Figure 6.2. Dynamic Model of Performance Characteristics in Soccer Goalkeepers.

A growing awareness of the bidirectional, dynamic, and continuous interactions between decision making, perception, and action (de Oliveira et al., 2009) illustrates the influential role of different constraints upon these interactions. For instance, a forward player is dribbling the ball inside the penalty area and sees a defender closing in and a team-mate appearing to his right. Being closer to the goal, the forward perceives the options to shoot at goal, pass the ball to the team-mate or challenge the defender. In this scenario, the goalkeeper readjusts his positioning for a closer covering to the defender, in an attempt to reduce the shooting angle, to cut the passing line and quickly move to a 1 *vs* 1 situation against the ball carrier in case the defender is left behind. So now, the forward player tries to pass to his right with the aim to dislocate the goalkeeper from his optimal positioning, and favouring the chances for goal scoring by his team-mate. This is a good example of how a player can affect the contextual situation by conditioning others (opponents and team-mates) perceptions, decisions and actions, and vice-versa. Data on perception–action coupling using the penalty situation as an experimental paradigm revealed that the utilisation of implicit (i.e., goalkeeper displacement) and explicit (i.e., pointing gestures) information strategies by the goalkeeper can systematically influence goal-side selection in the penalty taker (Weigelt, Memmert, & Schack, 2012; Wood & Wilson, 2010).

Ultimately, goalkeeping is about performing effective skilful actions under spatio-temporal constraints. Returning to the previous example, the goalkeeper faces a disadvantageous situation, where he perceives the options to stand in a balanced stance position for the shoot and react, or to leave the goal and move to a 1 *vs* 1 situation. A critical aspect for the success or failure of his action is dictated by his perceptual-motor skills. Following the assumption that in a penalty kick, the ball takes 0.6 s to reach the goal line when kicked at a speed of 75 km·h^{-1}(Kuhn, 1988), and the goalkeeper takes 0.6 to 1.0 s to dive from the centre of the goal to a corner location (Dicks, Uehara, & Lima, 2011), perceptual and cognitive skills will be decisive in preventing a goal. A recent study identified potential neural bases for perceptual-cognitive superiority in soccer anticipation task using functional magnetic resonance imaging (Bishop, Wright, Jackson, & Abernethy, 2013). High-skill anticipators were more attuned to both early kinematic information and deceptive movements than were their less-skilled counterparts. Finally, variability of experiences emphasizes the changing nature of the performer-environment relationship, and developing through training, practice, coaching and competing, i.e. having opportunities to optimize an individuals' potential.

6.5. What coaches need to know?

Researchers typically place higher priority on publication than do coaches, athletes, and officials, who really only want to identify effective strategies and interventions that can make a difference in performance and results (Pyne, 2012). However, coaching and research don't have to play antagonistic roles, rather than synergistic. This section of **Chapter 6** presents the available knowledge in more practical terms.

- Body size is an important feature in the identification, selection and development process of goalkeepers. Coaches seem to perceive body size as a crucial aspect in the effectiveness of goalkeeping actions in situations like shots, 1-on-1 challenges, dealing with crosses, or penalty kicks, as the goalkeeper takes a positioning to occupy larger areas of the goal or places additional constrains the opponent by narrowing down the shooting angle.
- When we're working with young athletes we don't control for body size. It's known that body size is mostly related to growth and maturation, and it affects power and strength. Coaches should be aware of this and recognize that performance characteristics have different timing and tempo, with important

implications to goalkeeping specific training and to long-term development programs.

- Trainers and coaches can benefit from the use of multilevel models in youth soccer. More precisely, by locating a goalkeepers in the estimated performance curves and determining if he is performing above or below average for his age and which factors may be responsible, i.e. which are his strengths and weaknesses.
- Looking at average values might set a good referential for those involved in talent identification and development programs. Nevertheless, testing batteries overlook the outliers (e.g., outperformers and late responders) over the mean. It is therefore suggested that focus should be place on the individual development, and on providing proper opportunities for the potentials' fulfilment.
- Generally, goalkeepers obtain the lowest results in aerobic protocols, which comes with no surprise given their distinct activity profile during a soccer match. Still, several authors recognized that the enhancement of this parameter is essential for a better adaptation and recovery during specific training (Deprez et al., 2015; Gil et al., 2007; Gil et al., 2014; Lago-Peñas et al., 2011; Wong et al., 2009). Predictive improvements in aerobic performance were higher from U-13 to U-15 and from U-17 to U-19, suggesting that these are particular periods to develop and enhance this physiological characteristic.
- Goalkeeping highlights anaerobic efforts of short-term duration when the goalkeeper is directly involved in the defensive (set play, shooting, crossing, through ball and 1 *vs* 1 challenges) and offensive (set play, ball in hand, build-ups and back pass) moments. Rather than applying maximal strength, these typical actions are largely related to an optimal use of the available strength on a given time/task.
- From the results displayed in **Study 4**, it was suggested that the design of goalkeeper-specific activities must focus on both eccentric and concentric actions, multi-directional movements during deceleration and acceleration to improve the stretch-shortening cycle, jump ability, and agility (Knoop et al., 2013). These activities might include Nordic hamstring, deadlift and lunges (Mendiguchia et al., 2014), single/double leg hop, lateral movements (step ups and shuffles), skipping, squats, low depth jumps and agility footwork.

- The principle of specificity is a key factor when planning training programs for goalkeepers (Ziv & Lidor, 2011), particularly in youth soccer. The aim should be to provide a variability of specific experiences by ensuring that the training conditions remain representative of game situations.
- In contemporary soccer, goalkeepers are required to interact more and more with their team-mates in the offensive moment, during which they have to handle the ball with their feet. **Study 1** and **2** emphasized the need to develop soccer-specific skills like passing, dribbling and shooting accuracy and to monitor the developmental changes of these aspects in youth soccer goalkeepers.
- The proposed tests in **Study 5** are recommended as practical instruments to assess and provide relevant information about the influence of several components of performance in the overall execution of a diving save (e.g. previous displacement, movement patterns, take-off movements and possible asymmetries).
- Although analytical forms might be appropriate to introduce and consolidate technical contents in the period before middle adolescence, as suggested in **Study 1**, it is desirable that training methodologies emphasizes the development of goalkeeping skills in a balanced combination with technical learning. The design of goalkeeper-specific activities must consider that successful goalkeeping actions during match-play are measured as an effective result of physical and technical responses in the minimal possible time.
- Goalkeepers should ultimately be prepared for anticipating the pathway and direction of the kicked ball (Lidor et al., 2012) and to produce effective actions in response to variation in visual information with the aim of decreasing movement time (Dicks et al., 2011). A study conducted with inexperienced goalkeepers (G. Savelsbergh et al., 2010) showed that the visual search behaviour of the perceptual learning group changed significantly and obtained a better performance than the training group and the control group.
- As discussed before, improving action in goalkeeping will likely influence perceptual-cognitive skills and plausibly, vice versa. If we're trying to develop aspects such as strength, agility and power, training should require goalkeepers to produce specific actions in response to visual information samples as per variations on game situations (Dicks et al., 2011). If resistance bands or weights

are used while performing different movements, it may be preferable to use it while the goalkeeper faces kicks that are preceded by a run-up rather than throw-feeds or drop-kicks.

- A goalkeeper could benefit from knowing the penalty takers preferred kick strategy and direction (Noël, van der Kamp, & Memmert, 2015). If the shooter adopts a keeper-dependent strategy (usually associated to a slowing down to the ball, using shorter strides and looking frequently at the goalkeeper) allows a goalkeeper to wait longer before starting a movement. A goalkeeper could try to identify a penalty kick strategy by focusing on the fluency of (the early parts of) the run-up and the kicker's gaze. If a penalty taker runs up steadily, while largely ignoring the goalkeeper, a keeper-independent strategy is more likely. The goalkeeper is then advised to dive early to the kicker's natural side.

6.6. Final conclusions

The main purpose of this thesis was to improve our general understanding of performance characteristics in young soccer goalkeepers, using a multidisciplinary approach. More than providing straightforward answers and definite conclusions, this thesis raised new questions and opened a challenging new way for approaching goalkeeping performance characteristics. Allowing for the variation in methods and materials and sampling in the presented studies on this thesis, it can be concluded that:

i. Playing position (goalkeeper *vs* outfield players) was especially associated with body size, physiological parameters and soccer skills in 145 soccer players aged 11–19 years, with the exception of goal orientation, vertical jump and ball control. Dribbling speed, shooting accuracy and passing tests were common predictors of playing position, while fat-free mass and ball control were important variables in middle and late adolescence, respectively.

ii. Chronological age was a consistent source of variation of aerobic performance, dribbling speed and passing skill. Multilevel modelling highlighted the importance of training in the development of soccer-specific skills.

iii. Reproducibility of estimated peak output and estimated pedal velocity was demonstrated, using a series of 3 to 5 maximal bouts of 10 s against a range of braking forces on a cycle ergometer.

iv. An effect of competitive level (national vs local) in maximal intensity short-term performance was displayed among 33 young soccer goalkeepers. Training experience, ratio knee flexors to knee extensors at 180º·s^{-1} was able to correctly predict 87.9% of goalkeepers into the original groups.

v. The Sprint-Keeper Test and the Lateral Shuffle-Keeper Test were reliable and valid testing measures to assess goalkeeper-specific technique. These field-based protocols can be particularly useful in the identification of asymmetries between diving sides, movement patterns and take-off movements.

From the studies in the current doctoral thesis, coaches and sport-scientists are advised to redirect the focus of their analysis to the continuous interactions between perception, decision making and (re)action. Goalkeeping involves effective skillful actions under spatio-temporal constraints in a dynamic context, where opponents and team-mates interact with goalkeepers. The individualistic nature of goalkeeping within a team sport, goes far beyond of being tall, brave, agile, fast, have a highly developed specific technique and a good jumping ability. To sustain a successful path to professional goalkeeping opportunities to optimize and individuals' potential must be provided. Coaches, trainers and other agents involved in youth soccer programs are strongly encouraged to review their goalkeeper-specific training curriculum and methodologies, when available.

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Chapter 7

Appendix A: Curriculum Vitae

1. PERSONAL AND PROFESSIONAL DATA

1.1. General information

Full name: Ricardo Rebelo Gonçalves
National identity card: 12585519
Date of Birth: July 24th, 1984
Place of Birth: Lisbon, Portugal
Institutional address: Faculdade de Ciências do Desporto, Estádio Universitário de Coimbra, Avenida Conímbriga, Pavilhão 3, 3040–248 Coimbra, Portugal.
Living address: Rua Professor Mota Pinto, Bloco C3, 3º direito. 3060–188 Cantanhede
Mobile Phone: +351 96 51 90 124
Email contact: r.rebelo.g@portugalmail.pt

1.2. Biography

Born in July 24th, 1984, in the city of Lisbon, Portugal. After finishing the secondary school in Cantanhede (2003), studied Sports Sciences the University of Beira Interior (Covilhã).After one year moved to the University of Coimbra where attained the degree of Graduate in Sport Sciences in the Faculty of Sport Sciences and Physical Education (2004–2008). During this period studied 1 semester in Charles University (Prague, Czech Republic), under the Erasmus program. Later obtained the Master degree in Sport Sciences – Sports Training for Children and Youth by the University of Coimbra (2008–2010) with the dissertation "Morphological and functional profile of young soccer goalkeepers". During the period of 2010–2015 was a PhD student in Sport Sciences in the branch of Sports Training (submitted and now waiting for public defence) and had earned a grant from the Portuguese Foundation for Science & Technology (FCT).

From 2008 till 2014 served as Goalkeeper Coach in the Youth Department (U-11 to U-23 age categories) of Associação Académica de Coimbra – Organismo Autónomo de Futebol. During the seasons of 2012/13 and 2013/14, accumulated the position of technical coordinator for youth goalkeeping. After a year of absence, is currently (2015/16) Goalkeeper Coach in the first team of Anadia Futebol Clube, competing in the 3rd level of the Portuguese soccer organization.

1.3. Interests

- Soccer training
- Talent identification and development programs
- Playing position specialization
- Sport expertise
- Sport-specific skills
- Perceptual cognitive skills
- Short-term maximal efforts

1.4. Academic degrees

Period: 2010-2015 (submitted and now waiting for public defence)
Academic degree: PhD in Sport Sciences in the branch of Sports Training
Institution: Faculty of Sport Sciences and Physical Education of the University of Coimbra, Portugal; University of Rome “Foro Italico, Italy.
Title: Multidisciplinary study of performance characteristics in soccer goalkeepers
Classification: N.A.

Period: 2008-2010
Academic degree: Master in Youth Sports Training
Institution: Faculty of Sport Sciences and Physical Education of the University of Coimbra, Portugal.
Title: Morphological and functional profile of young soccer goalkeepers
Classification: 17 on a scale of 0 to 20

Period: 2004-2008

Academic degree: Bachelor in Sports Sciences
Institution: Faculty of Sport Sciences and Physical Education of the University of Coimbra, Portugal.
Classification: 18 on a scale of 0 to 20

1.5. Outgoing missions

The University of Rome "Foro Italico" agreed to support the study entitled *"Multidimensional Study of Soccer Goalkeepers Performance Characteristics"*, being cooperative in an incoming of Ricardo Rebelo Gonçalves, during the period from February 5th to April 3rd. The mission promoted the production of at least one manuscript under the supervision of Antonio Tessitore. The incoming comprised data collection for study 5, and permitted free access to libraries, laboratories and other academic facilities.

1.6. Previous professional activities

Period: 2008–2011
Position or category: Physical Education Teacher
Institution: Câmara Municipal de Cantanhede, Portugal
Classification: N.A.

1.7. Participation in teaching activities as invited speaker

November 10th, 2014 – Bachelor in Sport and Wellbeing– Optional sport III and IV (Football): Global methodology for goalkeeper training. Polytechnic Institute of Leiria.
May 30th, 2013 – Bachelor Sports Sciences – Children's Sports.
May 28th, 2013 – Bachelor Sports Sciences – Children's Sports.
May 2nd, 2013 – Bachelor Sports Sciences – Children's Sports: Long-term preparation.
December 13th, 2012 – Bachelor Sports Sciences – Optional sport I (Football).

December 7th, 2012 – Bachelor Sports Sciences – Optional sport I (Football): Injury prevention.

December 6th, 2012 – Bachelor Sports Sciences – Optional sport I (Football): Strength training.

November 30th, 2012 – Bachelor Sports Sciences – Optional sport I (Football): Global methodology for goalkeeper training.

November 22th, 2012 – Bachelor Sports Sciences – Optional sport I (Football): Football specific demands.

November 9th, 2012 – MSc in Youth Sports Training – Growth and Maturation in young athlete: *Growing in Sports – An auxologic understanding (1st part): Age-related variation in anthropometric and maturity characteristics of soccer goalkeepers aged 11-14 years; Profiling the young soccer goalkeepers by competitive level. PhD Project presentation (2nd part): [SFRH/BD/72111/2010]: Multidimensional study of performance characteristics in soccer goalkeepers.*

May 28th, 2012 – Bachelor Sports Sciences – Children's Sports: Long-term preparation; Youth sports competitions.

May 23rd, 2012 – Bachelor Sports Sciences – Practical Studies I (Football): Goalkeeper-specific training – A new paradigma for na emerging understanding.

March 27th, 2012 – *Universitá degli Studi di Roma "Foro Italico"*, Master in Sport Sciences and Techniques – Team Sports: Goalkeeper specific training: New concepts and operacionalization.

March 8th, 2012 – *Universitá degli Studi di Roma "Foro Italico"*, Master in Sport Sciences and Techniques – Team Sports: Goalkeeper specific training: New concepts and operacionalization.

November 28th, 2011 – Bachelor Sports Sciences – Optional sport I (Football): Injury prevention.

November 21st, 2011 – Bachelor Sports Sciences – Optional sport I (Football): Strength training.

October 31st, 2011 – Bachelor Sports Sciences – Optional sport I (Football): Football specific demands.

October 3rd, 2011 – Bachelor Sports Sciences – Optional sport I (Football): Global methodology for goalkeeper-specific training.

September 29th, 2011 – MSc in Youth Sports Training – Auxology and Motor Development: *Growing in Sports – An auxologic understanding*.

1.8. Laboratory assessment experience

Anthropometry – Body size measures; Thigh volume measures

Estimated Body Composition – Air displacement plethysmography; Bioimpedance

Biological maturation – Skeletal Age (The Fels method: basic knowledge); Sexual maturity (pubic hair, genitals and testicular volume); Somatic Maturation (Maturity offset; Age at Peak Heigh Velocity; Predicted Mature Height)

Cycle Ergometer – Wingate Anaerobic Test; Force-Velocity Test

Isokinetic Dynamometry – Basic knowledge in the Biodex®

Questionnaires: TEOSQ; TACSIS

1.9. Field-test assessment experience

Aerobic Performance – 20 m shuttle run; Yo-Yo Intermittent Endurance and Recovery Test

Jump – Counter-movement jump; Drop Jump; Multiple Jump; Five-jump Test

Speed – Straight Sprint testing

Change of direction – T-Test; 10 x 5 m; Slalom Test

Repeated Sprint Ability – 7 Sprint Test; 12 x 20 m; Shuttle test;

Repeated Dribbling Ability – 7 Sprint Test [adapted by Duarte J. et al. (submitted)]

Soccer-specific Skills – Ball control; Dribbling speed; Shooting accuracy; Wass pass; Shuttle dribble test; slalom dribble test; Loughborough Soccer Passing Test

Goalkeeper-specific skills – S-Keeper; LS-Keeper

1.10. Network / Main Co-authors

António J. Figueiredo: Faculty of Sports Sciences and Physical Education, University of Coimbra, Portugal

Antonio Tessitore: University of Rome *"Foro Italico"*, Italy

João P. Duarte: Faculty of Sports Sciences and Physical Education, University of Coimbra, Portugal

João Valente-dos-Santos: Faculty of Sports Sciences and Physical Education, University of Coimbra, Portugal; Faculty of Physical Education and Sport, Lusófona University of Humanities and Technologies, Lisbon, Portugal

Manuel J. Coelho e Silva: Faculty of Sports Sciences and Physical Education, University of Coimbra, Portugal

Marije T. Elferink-Gemser: Center for Human Movement Sciences, University Medical Center Groningen, University of Groningen, Groningen; Institute for Studies in Sports and Exercise, The Netherlands; HAN University of Applied Sciences, Nijmegen, The Netherlands

Neil Armstrong: University of Exeter, UK

Robert M. Malina: Department of Kinesiology and Health Education, University ofTexas at Austin; Department of Kinesiology, Tarleton State University, Stephenville,United States

Vasco Vaz: Faculty of Sports Sciences and Physical Education, University of Coimbra, Portugal

Vítor Severino: Faculty of Sports Sciences and Physical Education, University of Coimbra, Portugal

2. SCIENTIFIC RESEARCH

2.1. Chapters in books

8) Rui Fernandes, Beatriz Gomes, **Ricardo Rebelo-Gonçalves**, João P. Duarte, João R. Pereira, A. Cupido-dos-Santos (2013). The anthropometric characteristics of young paddlers and their relationship with paddle set-up and performance. *In* M. J. Coelho-e-Silva, A. Cupido-dos-Santos, A. J. Figueiredo, J. P. Ferreira & N. Armstrong (Eds), *Children and Exercise XXVII: The Proceedings of the 28th Pediatric Work Physiology Meeting, October 2013 (pp. 269–272)*. London; New York: Routledge.

7) J. Castanheira, J. Valente-dos-Santos, M.J. Coelho-e-Silva, J. Duarte, J. Pereira, **R. Rebelo-Gonçalves**, V. Severino, A. Machado-Rodrigues, V. Vaz, L.B. Sherar, M.T. Elferink-Gemser, R.M. Malina (2013). Allometric Scaling of Left Ventricular Mass in Relation to Body Size, Fat-Free Mass and Maturation in 13-Year-Old Boys. *In* M. J. Coelho-e-Silva, A. Cupido-dos-Santos, A. J. Figueiredo, J. P. Ferreira & N. Armstrong (Eds), *Children and Exercise XXVII: The Proceedings of the 28th Pediatric Work Physiology Meeting, October 2013 (pp. 133–137)*. London; New York: Routledge.

6) João Duarte, Vítor Severino, João Pereira, Rui Fernandes, Filipe Simões†, **Ricardo Rebelo-Gonçalves**, João Valente-dos-Santos, Vasco Vaz, André Seabra, Manuel J Coelho-e-Silva *(2013). Reproducibility of Repeated Dribbling Ability. In* M. J. Coelho-e-Silva, A. Cupido-dos-Santos, A. J. Figueiredo, J. P. Ferreira & N. Armstrong (Eds), *Children and Exercise XXVII: The Proceedings of the 28th Pediatric Work Physiology Meeting, October 2013 (pp. 287–291)*. London; New York: Routledge.

5) Rafael Baptista, Amândio Cupidos-dos-Santos, João Duarte, João Rodrigues-Pereira, **Ricardo Rebelo-Gonçalves**, Vítor Severino, João Valente-dos-Santos, Manuel J Coelho-e-Silva, Carlos A Fontes-Ribeiro, Laura Capranica, Neil Armstrong(2013). Allometric Modelling of Anaerobic Peak Output Obtained from Force-Velocity protocol in Pubertal Boys. *In* M. J. Coelho-e-Silva, A. Cupido-dos-Santos, A. J. Figueiredo, J. P. Ferreira & N. Armstrong (Eds), *Children and Exercise XXVII: The Proceedings of the 28th Pediatric Work Physiology Meeting, October 2013 (pp. 293–296)*. London; New York: Routledge.

4) **Ricardo Rebelo-Gonçalves**, António Figueiredo, Vítor Severino, João Duarte, Filipe Simões†, João Valente-dos-Santos, João Pereira, Rui Fernandes, Vasco Vaz, Amândio Cupido-dos-Santos, Manuel J. Coelho-e-Silva, Antonio Tessitore, Neil Armstrong (2013). Agreement between anaerobic peak outputs obtained from the application of common braking force and the estimated optimal load in soccer goalkeepers. *In* M. J. Coelho-e-Silva, A. Cupido-dos-

Santos, A. J. Figueiredo, J. P. Ferreira & N. Armstrong (Eds), *Children and Exercise XXVII: The Proceedings of the 28th Pediatric Work Physiology Meeting, October 2013 (pp. 277–281)*. London; New York: Routledge.

3) Vítor Severino, Manuel J. Coelho-e-Silva, Filipe Simões†, João Duarte, João R. Pereira, João Valente-dos-Santos, **Ricardo Rebelo-Gonçalves**, Carlo Castagna, António J. Figueiredo (2013). Absolute and scaled peak power assessments in young male soccer players: variation by playing position. *In* M. J. Coelho-e-Silva, A. Cupido-dos-Santos, A. J. Figueiredo, J. P. Ferreira & N. Armstrong (Eds), *Children and Exercise XXVII: The Proceedings of the 28th Pediatric Work Physiology Meeting, October 2013 (pp. 257–261)*. London; New York: Routledge.

2) Figueiredo, A.J., Coelho-e-Silva, M.J., Severino, V.,**Rebelo Gonçalves, R.**, Peña Reyes, M.E. & Malina, R.M. (2012). Characteristics of contrasting skeletal maturity status at the beginning of long-term soccer training. *Growth and maturation in Human Biology and Sports: Festschrift honoring Robert M Malina by fellows and colleagues.*Peter Todd Katzmarzyk, Manuel J Coelho e Silva (Eds) (pp. 191–205). Coimbra: Imprensa da Universidade de Coimbra.

1) Severino, V., Coelho e Silva, M.J., **Rebelo Gonçalves, R.**, Figueiredo, A.J., Tessitore, A. & Castagna, C. (2011). Biological maturation and aerobic power in 11-year-old male soccer players. *In* M Jemni, A Bianco & A Palma. 2nd Edition of the *Book of Abstracts of the 1st International Conference on Science and Football*. Palermo, Italy: Scuolla dello Sport CONI Sicilia Publications.

2.2. Articles in peer review international journals

3) Luz, L. G., Seabra, A., Padez, C., Duarte, J. P., **Rebelo-Goncalves, R.**, Valente-Dos-Santos, J., . . . Coelho, E. S. M. (2016). Waist circumference as a mediator of biological maturation effect on children's performance at the motor coordination test. Rev Paul Pediatr. doi: 10.1016/j.rpped.2016.01.002.

2) **Rebelo-Goncalves, R.**, Coelho, E. S. M. J., Severino, V., Tessitore, A., & Figueiredo, A. J. (2015). Anthropometric and physiological profiling of youth soccer goalkeepers. Int J Sports Physiol Perform, 10(2), 224-231. doi:

10.1123/ijspp.**2014**-0181.

1) Valente-dos-Santos, J., J., Coelho, E. S. M. J., Duarte, J., Pereira, J., **Rebelo-Goncalves, R.**, Figueiredo, A., Mazzuco, M. A., Sherar, L. B., Elferink-Gemser, M. T., Malina, R. M. (2014). Allometric Multilevel Modelling of Agility and Dribbling Speed by Skeletal Age and Playing Position in Youth Soccer Players. *Int J Sports Med*. doi: 10.1055/s-0033-1358469.

2.3. Articles in peer review national journals

6) Rafael Baptista, João Valente-dos-Santos, Diogo Martinho, João Duarte, João Pereira, **Ricardo Rebelo-Gonçalves**, Vítor Severino, Ivo Rêgo, Amândio Cupido-dos-Santos, Laura Capranica, Manuel J. Coelho-e-Silva (2014). Allometric scaling of peak and mean outputs derived from 30 s wingate test in adolescent basketball players. *Annals of Research in Sport and Physical Activity, 5, 23-25*;dx.doi.org/10.14195/2182-7087_5_3.

5) **Ricardo R. Gonçalves**, António Figueiredo, Rui Fernandes, Filipe Simões, Manuel Coelho e Silva, Antonio Tessitore (2013). Diving technique in young soccer goalkeepers – reproducibility of two new tests. *Annals of Research in Sport and Physical Activity, 4, 63-66*;dx.doi.org/10.14195/2182-7087_4_7.

4) João P Duarte, Vítor Severino, João R Pereira, Rui Fernandes, Filipe Simões, **Ricardo Rebelo-Gonçalves**, João Valente-dos-Santos, Vasco Vaz, André Seabra, Manuel J Coelho e Silva (2013). Reproducibility of repeated dribbling ability. *Annals of Research in Sport and Physical Activity, 4, 51-54*; dx.doi.org/10.14195/2182-7087_4_4.

3) **Rebelo Gonçalves, R.** (2011). Maturity, anthropometric and functional characteristics of non-elite and sub-elite young soccer goalkeepers under-15. *Annals of Research in Sport and Physical Activity, 2,* 01/2011; DOI: 10.14195/2182-7087_2_17.

2) Severino, V., **Rebelo Gonçalves, R.**, Coelho e Silva M.J. & Figueiredo, A.J. (2011). Growth, maturity profile and peak VO2 of 11-year-old male soccer players. *Annals of Research in Sport and Physical Activity, 1.Imprensa da Universidade de Coimbra, 2*, DOI: 10.14195/2182-7087_2_3.

1) **Rebelo Gonçalves, R.**, Severino, V., Coelho e Silva M.J. & Figueiredo, A.J. (2011). Age-related variation in anthropometric and maturity characteristics of soccer goalkeepers aged 11-14 years. *Annals of Research in Sport and Physical Activity, 1.Imprensa da Universidade de Coimbra,* 2011 (ISSN: 2182-1143).

2.4. Abstracts in international conference proceedings

32) M.J. Coelho-e-Silva, J. Valente-dos-Santos, J. Pereira, **R. Rebelo-Gonçalves**, A.J. Figueiredo, M.A. Mazzuco, L.B. Sherar, M.T. Elferink-Gemser, R.M. Malina (2015). Developmental changes in short-term maximal intensity running protocols without and with ball control in adolescent soccer players: allometric multilevel modelling by playing position and skeletal maturation. Abstracts from the September 2015 Pediatric Work Physiology Meeting. Child Health: From Clinics to Classroom. Utrecht, the Netherlands. *Pediatric Exercise Science,* 2015, 27, 1 - 104, pp. 25.

31) **Ricardo Rebelo-Gonçalves**, António J. Figueiredo, João Valente-dos-Santos, Manuel João Coelho-e-Silva, Antonio Tessitore (2015). **Are acceleration and jumping related to goalkeeper-specific testing?***The 8th World Congress on Science and Football, Denmark, 20-23 May, 2015*. Program and Abstracts (ISBN: 978 87 9177 159 0); pp: 63.

30) **Rebelo-Gonçalves, R.**, Coelho-e-Silva, M.J., Tessitore, A., Figueiredo, A.J. (2014). Power assessment in young male soccer goalkeepers: variation by competitive level. In Carolina Vila-Chã, Mário Costa, Pedro Esteves (editors). *Abstracts Book of the CIDESD 2014 – International Congress of Exercise and Sports Performance.*Polytechnic Institute of Guarda, Portugal. pp: 37.

29) Baptista R, Cupido-dos-Santos A, Duarte JP, Pereira JR, **Rebelo-Gonçalves R**, Severino V, Valente-dos-Santos J, Rego I, Coelho-e-Silva MJ, Fontes-Ribeiro CA, Capranica L, Armstrong N (2013). Allometric modelling of peak power output obtained from a force-velocity protocol in prepubertal boys. In M Coelho-e-Silva, A Cupido-dos-Santos, A Figueiredo, J Ferreira, N Armstrong (editors). Book of abstracts of the 28th Pediatric Work Physiology Meeting. Anadia: University of Coimbra pp: 108.

28) Castanheira J, Valente-dos-Santos J, Duarte J, Pereira JR, **Rebelo-Gonçalves R**, Severino V, Machado-Rodrigues A, Vaz V, Figueiredo AJ, Coelho-e-Silva MJ, Sherar L, Elferink-Gemser MT, Malina RM (2013). Allometric scaling of left ventricular mass in relation to body size, fat-free mass and maturation in 13-year-old boys. In M Coelho-e-Silva, A Cupido-dos-Santos, A Figueiredo, J Ferreira, N Armstrong (editors). Book of abstracts of the 28th Pediatric Work Physiology Meeting. Anadia: University of Coimbra pp: 79.

27) Coelho-e-Silva, M., Carvalho, H.J.A., Batista, F., Baptista de-Almeida, J.M., Duarte, J., Pereira, J., Simões, F., **Rebelo-Gonçalves, R.**, Severino, V., Valente-dos-Santos, J., Vaz, V. (2013). Growth, maturation and peak ogygen uptake in adolescente basketball players. In N Balagué, C Torrents, A Vilanova, J Cadefeau, R Tarragó, E Tsolakidis (editors). Book of abstracts of the 18th annual Congress of the European College of Sport Science.

26) Coelho-e-Silva, M., Duarte, J., Pereira, J., Simões, F., **Rebelo-Gonçalves, R.**, Severino, V., Valente-dos-Santos, J., Ribeiro, L., Figueiredo, A.J., Malina, R.M. (2013). Agreement between maturity status derived from invasive "skeletal" and non-invasive "somatic" indicators of biological maturation in adolescent male soccer players. In N Balagué, C Torrents, A Vilanova, J Cadefeau, R Tarragó, E Tsolakidis (editors). Book of abstracts of the 18th annual Congress of the European College of Sport Science pp: 692.

25) Duarte J, Severino V, Pereira JR, Fernandes RA, Simões F, **Rebelo-Gonçalves R**, Valente-dos-Santos J, Vaz V, Seabra A, Coelho-e-Silva MJ (2013). Reproducibility of Repeated Sprint Ability. In M Coelho-e-Silva, A Cupido-dos-Santos, A Figueiredo, J Ferreira, N Armstrong (editors). Book of abstracts of the 28th Pediatric Work Physiology Meeting. Anadia: University of Coimbra pp: 110.

24) Duarte, J., Valente-dos-Santos, J., Pereira, J., Simões, F., **Rebelo-Gonçalves, R.**, Severino, V., Figueiredo, A., Elferink-Gemser, M., Malina, R.M., Coelho-e-Silva, M. (2013). Longitudinal predictors of aerobic performance in adolescent soccer players. In N Balagué, C Torrents, A Vilanova, J Cadefeau, R Tarragó, E Tsolakidis (editors). Book of abstracts of the 18th annual Congress of the European College of Sport Science pp: 510.

23) Duarte, J., Valente-dos-Santos, J., Pereira, J., Simões, F., **Rebelo-Gonçalves, R.**, Severino, V., Vaz, V., Figueiredo, A., Elferink-Gemser, M., Malina, R.M.,

Coelho-e-Silva, M. (2013). Maturity-associated developmental changes in change of direction and dribbling speed in young soccer players.In N Balagué, C Torrents, A Vilanova, J Cadefeau, R Tarragó, E Tsolakidis (editors). Book of abstracts of the 18th annual Congress of the European College of Sport Science pp: 689 [ISBN 978-84-695-7786-8].

22) João Duarte, João Pereira, **Ricardo Rebelo-Gonçalves**, Vítor Severino, João Valente-dos-Santos, Vasco Vaz, Manuel João Coelho e Silva (2013). Repeated Dribbling Ability in Youth Soccer: Test Proprieties, Interrelationship With Repeated Sprint Tests and Variation By Age Group. *In II International Congress of Sports* Training. Academic Institute of Maia, Portugal.

21) *Fernandes, RA., Gomes, BB.,* ***Rebelo-Gonçalves, R.****, Duarte, J., Pereira, JR., Santos, A.C. (2013). The anthropometric characteristics of young paddlers and its relationship with the performance in the 1000 meters race.*In N Balagué, C Torrents, A Vilanova, J Cadefeau, R Tarragó, E Tsolakidis (editors). Book of abstracts of the 18th annual Congress of the European College of Sport Science.

20) Fernandes, R.A.*, Gomes, B.B.,* ***Rebelo-Gonçalves, R.****, Duarte, J., Pereira, JR., Santos, A.C. (2013). The anthropometric characteristics of young paddlers and its relationship with the paddle set-up.*In M Coelho-e-Silva, A Cupido-dos-Santos, A Figueiredo, J Ferreira, N Armstrong (editors). Book of abstracts of the 28th Pediatric Work Physiology Meeting. Anadia: University of Coimbra.

19) Figueiredo, A.J., Severino, V., **Rebelo-Gonçalves, R.**, Santos, A.C., Castagna, C., Coelho-e-Silva, M.J. & Malina, R.M. (2013). Profiling 11-year-old male soccer players by position: size, maturation, aerobic fitness, training and competition time. *Book of Abstracts of theAmerican College of Sports Medicine - 60th Annual Meeting*. Indianapolis, Indiana – United States of America.

18) Pereira, J.R., Vaz, V., Valente-dos-Santos, J., Duarte, J., Simões, F., **Rebelo-Gonçalves, R.**, Severino, V., Cupido-dos-Santos, A., Elferink-Gemser, M.T., Malina, R.M., Coelho-e-Silva, M.J. (2013). Allometric scaling of peak oxygen uptake in under-17 male roller hockey players. In N Balagué, C Torrents, A Vilanova, J Cadefeau, R Tarragó, E Tsolakidis (editors). Book of abstracts of the 18th annual Congress of the European College of Sport Science pp: 512

17) **Rebelo-Gonçalves, R**, Figueiredo, A, Coelho e Silva, MJ, & Tessitore, A. (2013). Diving technique in young soccer goalkeepers – Reproducibility of two new tests. In N Balagué, C Torrents, A Vilanova, J Cadefeau, R Tarragó, E Tsolakidis (editors). Book of abstracts of the 18th annual Congress of the European College of Sport Science pp: 927.

16) **Rebelo-Gonçalves R**, Figueiredo AJ, Duarte JP, Pereira JR, Fernandes RA, Simões F, Severino V, Valente-dos-Santos J, Cupido-dos-Santos A, Coellho-e-Silva MJ, Tessitore A, Armstrong N (2013). Agreement between peak power outputs obtained from the application of common braking force and the estimated optimal load in soccer goalkeepers. In M Coelho-e-Silva, A Cupido-dos-Santos, A Figueiredo, J Ferreira, N Armstrong (editors). Book of abstracts of the 28th Pediatric Work Physiology Meeting. Anadia: University of Coimbra pp: 107.

15) Rêgo, Ivo António, Baptista, Rafael, Martinho, Diogo, Baptista-de-Almeida, José Miguel, Pereira, João, Duarte, João, Severino, Vítor, **Rebelo-Gonçalves, Ricardo**, Valente-dos-Santos, João, Manuel J Coelho-e-Silva (2013). Effects of size and maturation on cycling and running protocols before and after allometric scaling in youth basketball. In M Coelho-e-Silva, A Cupido-dos-Santos, A Figueiredo, J Ferreira, N Armstrong (editors). Book of abstracts of the 28th Pediatric Work Physiology Meeting. Anadia: University of Coimbra

14) *Rodrigues Ferreira, M.A., Mendes, J.,* ***Rebelo-Gonçalves, R.****, Fernandes, R., Fernando, C., Vences Brito, A.M. (2013). Peak* VO_2 *and peak power output in young soccer players.*In N Balagué, C Torrents, A Vilanova, J Cadefeau, R Tarragó, E Tsolakidis (editors). Book of abstracts of the 18th annual Congress of the European College of Sport Science.

13) Severino V, Coelho e Silva MJ, Duarte JP, Pereira JR, **Rebelo-Gonçalves R**, Valente-dos-Santos J, Castagna C, Figueiredo AJ (2014). Absolute and scaled peak power assessments in young male soccer players: variation by playing position. In M Coelho-e-Silva, A Cupido-dos-Santos, A Figueiredo, J Ferreira, N Armstrong (editors). Book of abstracts of the 28th Pediatric Work Physiology Meeting. Anadia: University of Coimbra pp: 97.

12) Simões, F., Coelho-e-Silva, M., Rama, L., Vaz, V., Duarte, J., Pereira, J., **Rebelo-Goncalves, R.**, Severino, V., Valente-dos-Santos, J., Courteix, D. (2013). Agreement between an anthropometric method of assessing lower limb volume and a reference method in female swimmers: Preliminary study. In N Balagué, C Torrents, A Vilanova, J Cadefeau, R Tarragó, E Tsolakidis (editors).

Book of abstracts of the 18th annual Congress of the European College of Sport Science.

11) V. Severino, M. J. Coelho-e-Silva, F. Simões†, J. Duarte, J. R. Pereira, J. Valente-dos-Santos, **R. Rebelo-Gonçalves**, C. Castagna, A. Figueiredo (2013). Profiling young soccer players by playing position: body size, body composition,maturation and short-term maximal effort. *Book of Abstracts of the 18th annual Congress of the European College of Sport Science*. In N Balagué, C Torrents, A Vilanova, J Cadefeau, R Tarragó, E Tsolakidis (editors). Book of abstracts of the 18th annual Congress of the European College of Sport Science pp: 933.

10) V. Severino, M. J. Coelho-e-Silva, F. Simões†, J. Duarte, J. R. Pereira, J. Valente-dos-Santos, **R. Rebelo-Gonçalves**, C. Castagna, A. Figueiredo(2013). Interpretation of Peak Power assessments in young soccer players. In N Balagué, C Torrents, A Vilanova, J Cadefeau, R Tarragó, E Tsolakidis (editors). Book of abstracts of the 18th annual Congress of the European College of Sport Science pp: 933.

9) Manuel Coelho-e-Silva, António Figueiredo, João Pereira, João Duarte, José H Colares-Pinto, Filipe Simões, Luis Ribeiro, **Ricardo Rebelo-Gonçalves**, Vitor Severino, João Valente-dos-Santos, Humberto Carvalho, Neiva Leite, Robert Malina (2012). Inter-individual variability in skeletal age determined by the Fels protocol: implications for age verification in youth soccer. In Book of Abstracts of the *3rd World Conference on Science and Soccer*. Ghent. Victoris & Gent BC. Pp: 100.

8) **Ricardo Rebelo-Gonçalves**, Humberto M Carvalho, Vítor Severino, João Duarte, João Pereira, J. Colares-Pinto, Filipe Simões, João Valente-dos-Santos, Amândio Santos, António Figueiredo, Antonio Tessitore, Neil Armstrong, Manuel J Coelho-e-Silva (2012). Relationship of the peak power assessments using the Wingate Anaerobic Test and a Force-Velocity Test in soccer goalkeepers. Book of Abstracts of the *3rd World Conference on Science and Soccer*. Ghent. Victoris & Gent BC. Pp:267.

7) Severino, V., Coelho-e-Silva, M.J., Duarte, J., Simões, F., **Rebelo-Gonçalves, R.**, Valente-dos-Santos, J., Carvalho, H., Vaz, V., Santos, A.C., Castagna, C. & Figueiredo A.J. (2012). Inter-relationship between skeletal maturation and peak VO2 before and after normalization for body size in youth soccer players.Book of Abstracts of the *3rd World Conference on Science and Soccer*. Ghent. Victoris & Gent BC. Pp:229.

6) Valente-dos-Santos J, Coelho-e-Silva MJ, China NB, Pereira J, Duarte J, Simões F, Severino V, **Gonçalves R**, Carvalho H, Figueiredo AJ, Elferink-Gemser M and Malina RM (2012). Modelling repeated-sprint ability by skeletal maturity status in young soccer players. Book of Abstracts of the *3rd World Conference on Science and Soccer*. Ghent. Victoris & Gent BC. Pp:230.

5) Figueiredo, A.J., Severino, V., **Gonçalves, R.**, Simões, F., Coelho e Silva, M.J. & Malina R.M. (2011). Time loss injury-associated variation in the profile of soccer players 11-12 years of age. In *Football Science* (Eds). *Book of abstracts 7th World Congress on Science & Soccer*. *Japanese Society of Science & Football*. Nagoya. pp: 131.

4) **Rebelo Gonçalves, R.**, Coelho e Silva, M.J., Severino, V., Tessitore, A. & Figueiredo, A.J. (2011). Profiling the young soccer goalkeepers by competitive level. In Monèm Jemni, Antonino Bianco, Antonio Palma (editors). *Proceedings of the 1st International Conference on Science and Football, 15-17 April 2011, Palermo – Italy* pp. 65.

3) Severino, V., Coelho e Silva, M.J., **Rebelo Gonçalves, R.**, Castagna, C., Santos, A.C. & Figueiredo, A.J. (2011). Biological maturation and aerobic power in 11-year-old male soccer players. In Monèm Jemni, Antonino Bianco, Antonio Palma (editors). *Proceedings of the 1st International Conference on Science and Football, 15-17 April 2011, Palermo – Italy* pp. 78.

2) **Rebelo Gonçalves, R.**, Severino, V., Gil, N., Figueiredo, A.J. & Coelho e Silva, M.J. (2009). Morphological and maturity profile of young soccer goalkeepers with 11-13 years of age. *In* S Loland, K Bo, K Fasting, J Hallén, Y Ommundsen, G Roberts & E Tsolakidis. *Book of Abstracts of the 14th annual Congress of the European College of Sport Science*. Norwegian School of Sport Sciences, Oslo. Norway pp. 246.

1) Severino, V., **Rebelo Gonçalves, R.**, Simões, F., Rêgo, I., Mazzuco, M., Figueiredo, A.J., Páscoa Pinheiro, J. & Coelho e Silva, M.J. (2009). Risk for time loss injury and skill level among 11-to-12-year-old male soccer players. *In* S Loland, K Bo, K Fasting, J Hallén, Y Ommundsen, G Roberts & E Tsolakidis. *Book of Abstracts of the 14th annual Congress of the European College of Sport Science*. Norwegian School of Sport Sciences, Oslo. Norway pp. 56.

2.5. Grants

PhD Project Funded by the Portuguese Foundation for Science & Technology (Ministry of Education and Science) (2011 - 2015):

Ricardo Rebelo Gonçalves [SFRH/BD/72111/2010]. *Multidimensional Study of Performance Characteristics in Soccer Goalkeepers.* Advisors: António Figueiredo, PhD (University of Coimbra, Portugal), Manuel Coelho e Silva, PhD (University of Coimbra, Portugal) & Antonio Tessitore, PhD (Department of Human Movement and Sport Sciences, University of Rome *"Foro Italico"*, Italy).

2.6. Participation as member of a jury of Master's thesis

4. Ricardo Jorge João de Almeida Figueiredo (2014). *Desempenho em Provas Maximais Concorrentes de Curta e Média Duração: Variação por posição em futebolistas dos 15 aos 18 anos de idade*. MSc in Youth Sports Training. Faculty of Sports Sciences and Physical Education, University of Coimbra, Portugal. Jury: PhD António Figueiredo, PhD Vasco Vaz, PhD Manuel João Coelho e Silva, MSc **Ricardo Rebelo Gonçalves** [approved: 17/20: in 30/10/2014].
3. Marco Paulo Gaspar Ramos de Abreu (2011). *Selecção Desportiva de Jovens Futebolistas: Estudo comparativo por nível de prática em jogadores da Associação de Futebol de Viseu*. MSc in Youth Sports Training. Faculty of Sports Sciences and Physical Education, University of Coimbra, Portugal. Jury: PhD António Figueiredo, PhD Manuel João Coelho e Silva, Alain Massart, MSc **Ricardo Rebelo Gonçalves** [approved: 17/20: in 02/12/2011].
2. Laidiston Sales Godinho (2011). *Caracterização métrica e funcional de futebolistas sub-15: Estudo de defesas laterais e médios-centro com o recurso do Global Positioning System (GPS)*. MSc in Youth Sports Training. Faculty of Sports Sciences and Physical Education, University of Coimbra, Portugal. Jury: PhD Manuel João Coelho e Silva, PhD António Figueiredo,

PhD Vasco Vaz, PhD Luis Vaz, MSc **Ricardo Rebelo Gonçalves** [approved: 17/20: in 10/03/2011].

1. João Miguel Jorge de Sousa (2010). *A Tomada de Decisão em Jovens Futebolistas: O momento de transição defesa-ataque*. MSc in Youth Sports Training. Faculty of Sports Sciences and Physical Education, University of Coimbra, Portugal. Jury: PhD Manuel João Coelho e Silva, PhD António Figueiredo, PhD Luís Rama, PhD Vasco Vaz, MSc **Ricardo Rebelo Gonçalves** [approved: 17/20: in 27/01/2011].

3. TRANSFER AND USE OF KNOWLEDGE

3.1. Oral communications in international specialized training

12) **Ricardo Rebelo-Gonçalves**, António J. Figueiredo, Manuel João Coelho-e-Silva, Antonio Tessitore (2015). Avaliação do Desempenho Técnico do Jovem Guarda-redes. *VII International Meeting of Soccer Coaches, May 29–30th, 2015.* Auditório do CCP, Vila Nova de Poiares, Portugal.

11) **Ricardo Rebelo-Gonçalves**, António J. Figueiredo, João Valente-dos-Santos, Manuel João Coelho-e-Silva, Antonio Tessitore (2015). Are acceleration and jumping related to goalkeeper-specific testing? *The 8th World Congress on Science and Football, Denmark, 20-23 May, 2015*. Program and Abstracts (ISBN: 978 87 9177 159 0). pp: 63.

10) **Rebelo-Gonçalves, R.**, Coelho-e-Silva, M.J., Tessitore, A., Figueiredo, A.J. (2014). Power assessment in young male soccer goalkeepers: variation by competitive level. In Carolina Vila-Chã, Mário Costa, Pedro Esteves (editors). *Abstracts Book of the CIDESD 2014 – International Congress of Exercise and Sports Performance.*Polytechnic Institute of Guarda, Portugal. pp: 37.

9) Manuel João Coelho e Silva, João Valente-dos-Santos, João Pereira, João Duarte, **Ricardo Rebelo-Gonçalves**, Vítor Severino, Vasco Vaz, António J Figueiredo, Robert M Malina (2013). Growth, Maturity and Talent: cross-sectional, longitudinal and retrospective evidences. *In II International Congress of Sports* Training. Academic Institute of Maia, Portugal.

8) **Rebelo-Gonçalves, R**, Figueiredo, A, Fernandes, R, Simões, F, Coelho e Silva, MJ, & Tessitore, A (2013). Diving technique in young soccer goalkeepers – Reproducibility of two new tests. *IP-SMEC: Intensive programme Sport as a mean for European citizenship, February 4–15th, 2013.* Faculty of Sports Sciences and Physical Education, University of Coimbra, Portugal.
7) **Ricardo Rebelo-Gonçalves** (2013). Young Goalkeepers: Selection and Development. *Conferência Internacional de Treinadores, May 24–25th, 2013.* Estádio Efapel Cidade de Coimbra, Academia Dolce Vita, Coimbra, Portugal.
6) Duarte, J., Carvalho H.M., Valente-dos-Santos, J., Severino, V., **Rebelo-Gonçalves, R.**, Vaz, V., Figueiredo, A.J. & Coelho-e-Silva, M.J. (2012). Assessment of repeated dribbling ability in young soccer players. *Intensive Programme Sport Performance: A Lifetime Challenge (IP-Spalc). University of Rome "Foro Italico". Rome – Italy*. February, 5–19, 2012.
5) Manuel Coelho-e-Silva, António Figueiredo, João Pereira, João Duarte, José H Colares-Pinto, Filipe Simões, Luis Ribeiro, **Ricardo Rebelo-Gonçalves**, Vitor Severino, João Valente-dos-Santos, Humberto Carvalho, Neiva Leite, Robert Malina (2012). Inter-individual variability in skeletal age determined by the Fels protocol: implications for age verification in youth soccer. In Book of Abstracts of the *3rd World Conference on Science and Soccer*. Ghent. Victoris & Gent BC. pp: 100.
4) **Ricardo Rebelo Gonçalves** (2012). Avaliação multidimensional do desempenho do guarda-redes de futebol. *VI International Meeting of Soccer Coaches, September 23th, 2012.* Auditório Biblioteca Miguel Torga, Arganil, Portugal.
3) **Ricardo Rebelo Gonçalves** (2012). A new paradigm for an emerging understanding of goalkeeper teaching/training. *I Joint Conference for Football Coaches, May 25–27th, 2012.* Myerscough College, Preston. England.
2) **Rebelo Gonçalves, R.** (2011). Maturity, anthropometric and functional characteristics of non-elite and sub-elite young soccer goalkeepers under-15. *Intensive Programme: Sport Performance a lifespan challenge 2, May 9–21th, 2011.* University of Rome Foro Italico. Rome, Italy.
1) **Ricardo Rebelo Gonçalves**, Manuel J. Coelho e Silva e António J. Figueiredo (2009). Morphological and functional profile of young soccer goalkeepers

throughout the training process. *IV International Meeting of Soccer Coaches, September 18th, 2009.* Auditório Biocant Park, Cantanhede, Portugal.

3.2. Oral communications in national specialized training

4) **Ricardo Rebelo-Gonçalves** (2013). *Multidimensional study of performance characteristics in soccer goalkeepers*. V Summer Course in Sports Sciences, July 5th, 2013. Faculty of Sports Sciences and Physical Education, University of Coimbra.

3) **Ricardo Rebelo-Gonçalves** (2013). *Agreement between anaerobic peak outputs obtained from standardized and estimated optimal load in soccer goalkeepers*. V Summer Course in Sports Sciences, July 5th, 2013. Faculty of Sports Sciences and Physical Education, University of Coimbra.

2) **Ricardo Rebelo Gonçalves** (2011). Global Methodology for Goalkeeper-specific Training. 1º Colóquio Futebol Formação – Ensinar Futebol, October 15th, 2011. Pavilhão da Escola "Rumo ao Futuro", Clube Amador de Desportos do Entroncamento, Portugal.

1) **Ricardo Rebelo Gonçalves** (2010). Futebol: Metodologia Global para o Treino Específico do Guarda-redes de Futebol. *Organização e Planeamento do Futebol Juvenil, October 30–31st and November 1st, 2010*. Associação de Futebol de Angra do Heroísmo, Divisão de Desporto da Ilha de São Jorge, Açores, Portugal.

4. SPORTS EXPERIENCE

4.1. Career as an athlete

1998–2000 and 2001–2003: Clube de Futebol "Os Marialvas". Soccer, Goalkeeper. Regional Championship, Coimbra. Portugal.

1996–1997: Pombais Sport Clube, Odivelas. Futsal, Goalkeeper. Regional League. Portugal.

1995–1997: Centro Karate-Do Shotokan de Odivelas. Won 2 medals in Regional championships: 2nd place in Kata, 3rd place in Kumite. Portugal.

4.2. Coaching habilitations

2016 (currently performing the internship component): UEFA "B" License, Level 2 License Portuguese Soccer Association.

2008: UEFA "C" Licence, Level 1 License Portuguese Soccer Association.

4.3. Soccer coaching positions

2015-2016: Anadia Futebol Clube. Portugal

- First team, Goalkeeper Coach. National Senior Championship

2013-2014: Associação Académica de Coimbra – Organismo Autónomo de Futebol. Portugal.

- Under-19, Goalkeeper Coach. Portuguese National Championship
- Under-23, Goalkeeper Coach. Regional Championship
- Technical coordinator for youth goalkeeping

2012-2013: Associação Académica de Coimbra – Organismo Autónomo de Futebol. Portugal.

- Under-19, Goalkeeper Coach. Portuguese National Championship
- Under-11 and Under-13, Goalkeeper Coach. Regional Championship
- Technical coordinator for youth goalkeeping

2011-2012: Associação Académica de Coimbra – Organismo Autónomo de Futebol. Portugal.

- Under-15, Goalkeeper Coach. Portuguese National Championship
- Under-14, Goalkeeper Coach. Regional Championship

2010-2011: Associação Académica de Coimbra – Organismo Autónomo de Futebol. Portugal.

- Under-15, Goalkeeper Coach. Portuguese National Championship
- Under-14, Goalkeeper Coach. Regional Championship

2009-2010: Associação Académica de Coimbra – Organismo Autónomo de Futebol. Portugal.

- Under-17, Goalkeeper Coach. Portuguese National Championship
- Under-16, Goalkeeper Coach. Regional Championship

2008-2009: Associação Académica de Coimbra – Organismo Autónomo de Futebol. Portugal.

- Under-17, Goalkeeper Coach. Portuguese National Championship
- Under-16, Goalkeeper Coach. Regional Championship

4.4. Visiting coaching positions

February, 7–13th, 2014: FC Schalke 04, Gelsenkirchen, Germany.

The visiting period aimed to:

1) Understand the structure and interaction of coaches within Youth Academy;
2) Understand the organization and practical implementation behind the methodology applied in Schalke's youth teams;
3) Share practical and methodological issues with the Head Academy and Technical Coordinator of Goalkeeping;
4) Understand the role of strength and conditioning staff in the development of young players;
5) Acknowledge the full process and development of football players according to Schalke's methodology.

January 28th to July 4th, 2008: Associação Académica de Coimbra – Organismo Autónomo de Futebol. Portugal.

- Youth Department: Goalkeeper-specific training.

February 21st to May 17th, 2007: Associação Académica de Coimbra – Organismo Autónomo de Futebol. Portugal.

- First Team: Goalkeeper-specific training