Identification of relevant anthropometric indicators in youth male soccer players

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Abstract
This study aimed to identify key body composition traits that differentiate young soccer players. Fifty-nine male athletes (age: 15.97 ± 0.49 years) from a soccer academy participated in this research. The selected participants underwent standardized physical and anthropometric assessments. Principal Component Analysis (PCA) was used to identify the most essential physical variables relevant to the sport, with a recommended factor loading of > 0.7. To refine factor selection, a Parallel Analysis (PA) was conducted. The reliability of the extracted factors was evaluated using Cronbach's alpha. Following Varimax rotation, the PCA revealed three principal components (PCs) with eigenvalues greater than 1. However, the PA further reduced the number of extracted PCs to two. The retained components accounted for 71.23% of the total variance. Each of the two components contained variables selected based on their high factor loadings. The first PC demonstrated strong loadings from mid-thigh girth (0.867), body fat percentage (0.851), thigh girth (0.848), and calf girth (0.825). The second PC highlighted lower limb length (0.896), standing height (0.782), sitting height (0.773), and thigh length (0.736). The reliability of the extracted PCs was confirmed, with Cronbach's alpha coefficients of 0.866 and 0.789 for the first and second PCs, respectively.

Keywords: team sports, dimensional analysis, body metrics, athletic profiling.

Introduction

Soccer clubs invest substantial resources in detecting talented players with soccer-specific abilities, supposedly predictive of future career success [1]. Commonly, for talent identification coaches base their criteria on personal knowledge and experience [1, 2]. However, in modern soccer, talent identification assessments have been complemented with evidence-based procedures, to increase the probability of selecting successful players [1]. As a result, talent-related research has seen the integration of multidimensional and comprehensive models that detail prerequisites and predictors of successful adult performance [3, 4, 5].

According to Nevill et al. [6], and Nevill et al. [7], individual differences in athletic performance are affected by genetic factors. In this context, Lovell et al. [8] revealed that anthropometric characteristics such as body length are more genetically determined compared with physical fitness attributes. Therefore, anthropometric characteristics are key for the early recognition/detection of talented soccer athletes [9, 10]. Earlier studies demonstrated that differences in general anthropometric characteristics (e.g., body mass, whole body height, body-fat) may confound measures of athletic performance (e.g., muscle strength, muscle power, cardiorespiratory endurance, CoD speed) in soccer [11, 12]. For instance, Negra et al. [13] showed that youths who are more mature and have a lower fat mass and a shorter trunk length are likely to achieve a better change of direction speed performance. The same authors highlight the relevance of considering anthropometric characteristics in young male soccer players to support talent identification. Likewise, Negra et al. [14] reported large-to-very large associations between the Illinois change of direction speed test, and body mass, height, and leg length (r= -0.58, -0.75, and -0.75, respectively) in youth male soccer players aged 12 years. Los Arcos et al. [15] found that increased fat mass is associated with decreased change of direction speed performance (i.e., 180° CoD test) in elite male soccer players aged 19 years. Other studies [7, 16] pointed to the importance of considering more detailed anthropometric characteristics to better predict athletic performance in trained populations in comparison with more general characteristics (e.g., whole-body height). For instance, Sammoud et al.[17], showed the importance of assessing detailed anthropometric characteristics in young male and female breaststroke swimmers for talent identification.

It is necessary to use sound screening criteria for these components with specific end goals to improve athletic performance. An important aspect of the coaching process is accurate data from research. Competitive performance is the foundation that provides the goal of evaluation. The role of the sports scientist in the soccer process is to act as a vehicle for linking novel innovation and research to practice and play in the setting of the game. Principal component analysis (PCA) is a powerful statistical technique that involves identifying patterns from groups of observations or specific parameters. It provides insights into essential components by considering spatial and temporal variations that explain the entire data set, thereby excluding less important components without losing the original information in the data [18] PCA is extremely important for extracting the most needed information from large data sets. This helps save time, cost, and effort because the original information is usually retained. The use of PCA is very novel in the field of exercise and exercise science [19]. Nonetheless, numerous studies have reported that the dimensionality of huge data sets can be reduced by using PCA, which is considered one of the most widely used and useful statistical methods for revealing the underlying structure of a set of variables [18].

Thus, this study aimed to describe the set of anthropometric characteristics, that significantly discriminate young male soccer players using Exploratory Factor Analysis.

The research addresses the need for scientifically identifying key anthropometric characteristics that differentiate young male soccer players, aiding in talent identification and selection. The problem is analyzed through standardized physical assessments and statistical techniques such as Principal Component Analysis (PCA) to determine the most significant biometric variables. The study's findings emphasize the importance of body composition traits like mid-thigh girth and body fat percentage, as well as height-related measurements, for selecting youth soccer players, thereby contributing valuable insights to the field of sports science.

Material and Methods

Subjects

We performed a sample size calculation prior to recruitment using the G*Power software (Version 3.1.9.7, University of Kiel, Kiel, Germany), based on the results of a similar study conducted by Abdullah et al. [9]. The type I error rate was set at 0.05, with a statistical power of 80%. This analysis indicated that a sample size of 57 subjects would be sufficient.

All participants were in good health and had not experienced any musculotendinous injuries in the six months leading up to the study. A total of 59 youth male soccer players (age: 15.97 ± 0.49 years, height: 175.02 ± 5.23 cm, body mass: 59.06 ± 0.79 kg) participated in this study. Each had been involved in formal training and competition for at least five years.

All participants and their legal representatives were thoroughly informed about the testing and training procedures, as well as the potential benefits and risks associated with the study. Verbal assent was obtained from the participants (children), and written informed consent was secured from their legal representatives before the start of the experiment. The experimental procedures, along with any associated potential risks, were fully explained, and written informed consent (from parents/legal guardians) and assent (from participants) were obtained before the study commenced. All procedures were approved by the local Institutional Review Committee of the blinded for review and were conducted in accordance with the latest version of the Declaration of Helsinki.

Experimental Approach to the Problem

To identify the relevant anthropometric characteristics that distinguish young male soccer players, several measurements were taken, including body mass, standing height, sitting height, triceps skinfold, biceps skinfold, suprailiac skinfold, subscapular skinfold, lower limb length, thigh length, thigh girth, mid-thigh girth, and calf girth. The participants' body compositions were then calculated using the formula by Durnin and Womersley [20].

$$\text{Density} = 1.1533 - (0.0643 \times \text{Log} (\textstyle\sum \text{ of the 4 skinfolds (mm)}))$$

$$\%\,Body\ Fat = \left(\frac{4.95}{Density} - 4.50\right) \times 100$$

This study aimed to identify the most discriminative anthropometric measures among the players involved, selected from a random sample of 59 players drawn from the initial 64 volunteers.

Anthropometric Measurements

All anthropometric measurements were taken by a trained anthropometrist, assisted by a recorder, following the standardized procedures of the International Society for the Advancement of Kinanthropometry [21]. Testing was conducted in a standardized sequence after proper calibration of the measuring instruments. Each player’s height (in cm) and body mass (in kg) were measured to the nearest 0.1 cm and 0.1 kg, using a Seca stadiometer and a Seca weighing scale (Seca Instruments Ltd, Hamburg, Germany), respectively. Skinfold measurements (in millimeters) were taken on the right side of the body at four sites (triceps, biceps, suprailiac, and subscapular) using Harpenden skinfold calipers (Harpenden Instruments, Cambridge, UK).

All tests were scheduled at least 48 hours after the players' last training session or match, conducted at the same time of day (8:00–9:30 a.m.), and under consistent environmental conditions (16–18°C, no wind).

The following limb lengths and girths were assessed using a large sliding caliper and a non-stretchable tape measure through direct measurement techniques using anatomical landmarks: thigh length, leg length, thigh girth, mid-thigh girth, and calf girth. Thigh length was determined as the distance between the marked trochanterion and tibiale lateral landmarks. Leg length was measured from the tibiale lateral height to the top of the box (or the floor). Thigh girth was measured at the marked mid-trochanterion-tibiale lateral site. Calf girth was defined as the maximum girth of the calf, taken at the marked medial calf skinfold site. Body Mass Index (BMI) was calculated using the formula: BMI = body weight (kg) / height² (m²).

Statistical Analyses

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Data analyses were conducted using SPSS software (Version 20.0 for Windows, SPSS Inc., Chicago, IL, USA), with the level of statistical significance set a priori at 0.05. Initially, all data were examined for statistical outliers using Z scores. Four outliers were identified and removed from the analyses. The assumption of normality was checked and confirmed using the Kolmogorov-Smirnov test ($p > 0.05$).The intercorrelation matrix of all selected variables was then factorized using Principal Component Analysis (PCA). Factor analysis was performed using the PCA extraction method with Varimax rotation and Kaiser normalization. Factors were retained based on a Kaiser-Meyer-Olkin (KMO) index greater than 0.80 and a significant chi-square value. Varimax rotation was chosen because it is the most suitable method when data reduction is the primary objective. A factor was extracted if its eigenvalue was greater than one [22].
To ensure the quality of the extraction of the most significant anthropometric variables, a parallel correlation was conducted [23, 24]. Cronbach's alpha was used to assess the reliability of the extracted factors [25], with a value of 0.7 or higher indicating acceptable internal consistency [22].

Results
The Z score analysis identified four subjects as outliers, leading to their exclusion from our data set. The arithmetic means, standard deviations, as well as the minimum and maximum values of the players' body dimensions, are presented in Table 1. Factor analysis was employed to simplify and clarify the relationships between the anthropometric variables within the data set. The correlations among the anthropometric variables are shown in Table 2.

Table 1. Anthropometric and physical characteristics of youth soccer players

Parameter	Mean	SD	Min	Max
Age (year)	15.97	0.49	15.27	17.01
Height (cm)	175.02	5.23	164.50	186.60
Sitting height	83.85	2.70	78.50	90.00
Leg length (cm)	85.47	3.95	74.00	96.00
Thigh length	41.40	2.31	34.50	47.00
Body mass (kg)	59.06	0.79	48,50	74,00
Fat mass (%)	10.78	2.45	5.45	18.31
Thigh girth (cm)	50.29	3.57	43.00	61.00
Mid-thigh girth (cm)	46.83	3.65	40.00	57.50
Calf girth (cm)	29.00	37.00	1.97	33.66
BMI ($kg.m^{-2}$)	19.26	1.65	15.78	23.36

Table 2. Relationship between anthropometric parameters.

Correlation		Height (cm)	Sitting H (cm)	Leg length (cm)	Thigh L (cm)	BM (kg)	Fat mass (%)	Thigh G (cm)	Mid-thigh G (cm)	Calf G (cm)
Height (cm)	R	1								
	P									
Sitting height (cm)	R	0.713	1							
	P	0.000								
Leg length (cm)	R	0.564	0.506	1						
	P	0.000	0.000							
Thigh length (cm)	R	0.301	0.316	0.821	1					
	P	0.020	0.015	0.000						
Body mass (kg)	R	0.563	0.505	0.372	0.367	1				
	P	0.00	0.00	0.00	0.00					

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Fat mass (%)	R	-0.050	-0.078	-0.139	-0.22	0.498	1			
	P	0.96	0.55	0.29	0.87	0.00				
Thigh girth (cm)	R	0.180	0.243	0.207	0.345	0.593	0.604	1		
	P	0.17	0.06	0.11	0.00	0.00	0.00			
Mid-thigh girth (cm)	R	0.277	0.254	0.140	0.228	0.587	0.595	0.834	1	
	P	0.03	0.05	0.29	0.08	0.00	0.00	0.00		
Calf girth (cm)	R	0.341	0.277	0.182	0.136	0.706	0.606	0.606	0.652	1
	P	0.00	0.03	0.16	0.30	0.00	0.00	0.00	0.000	

The component statistics, Bartlett's test of sphericity, KMO, and parallel analysis measures of sampling adequacy of the PCA for the anthropometric variables are presented in Table 3. The principal components model accounted for 82.64% of the total variance.

Table 3. Component statistics, Bartlett's Test, KMO Measure, and Parallel Analysis for anthropometric variables

Variables	**Factors**		
	1	2	3
Eigenvalues			
Real data eigenvalue	4.20	2.13	1.02
Random data eigenvalue	1.87	1.55	***1.35***
% of variance	46.65	24.58	11.40
Cumulative %	46.65	71.23	82.63
Bartlett's test of sphericity			
χ^2		363.11	
P		0.000	
Overall KMO		0.73	
│R│ - *(Determinant)*		0.001	
Notes: R│: R-matrix; KMO: Kaiser-Meyer-Olkin measure of sampling adequacy:			

The rotated factor loading between the scores of nine tasks and the retained factors are presented in Table 4.

Table 4. Rotated Factor Loadings for Anthropometric Variables

Variables	**Factor**	
	1	**2**
Mid-thigh girth	***0 .867***	0.165
% Fat Mass	***0.851***	-0.224
Thigh Girth	***0.848***	0.190
Calf girth	***0.825***	0.200
Body Mass	0.713	0.503
Lower Limb length	-0.005	***0.896***
Height	0.184	***0.782***
Sitting Height	0.148	***0.773***
Thigh Length	0.096	***0.736***
Bold values represent loadings greater than ±.722 (Stevens, 2002)		

The first and second factors had eigenvalues of 4.20 and 2.21, respectively, explaining 71.23% of the total variance. Cronbach's alpha was 0.866 for Factor 1 and 0.789 for Factor 2.

Discussion

This study aimed to identify a set of anthropometric characteristics that significantly distinguish young male soccer players. The key findings of this study were that PCA reduced the collected data to two main somatic factors: the cubic content factor (including mid-thigh girth, % fat mass, thigh girth, and calf circumference) and the vertical dimension factor (lower limb length, height, sitting height, and thigh length). Soccer performance relies on a complex combination of physical fitness, strategy, tactical ability, technical skills, psychological traits, and anthropometric characteristics [26, 27]. Candidates for specific sports disciplines require particular physical attributes [28]. Anthropometric characteristics (e.g., height, body mass, biceps/triceps, subscapular, and suprailiac measurements) are crucial factors that influence success in soccer [29, 30] and are among the criteria considered during the selection process of potential players [30, 31, 32, 33, 34, 35].

PCA is a powerful statistical method used to identify patterns within an observed group or set of parameters [9]. It is considered one of the most widely used and effective statistical techniques for uncovering the underlying structure of a set of variables [36]. In our study, we initially examined the relationships between the variables using Bartlett's test of sphericity. The test was significant (Table 3), indicating that at least one of the correlations between the variables was significantly different from zero. Additionally, we performed the KMO test to assess the adequacy of the sampling and ensure a reasonable interpretation based on the collected data. The sampling adequacy in our study was 0.73%, confirming that the sampling measure was satisfactory [37].

As shown in Table 3, the PCA identified three components as the most important due to their eigenvalues being greater than one. The "scree plot" (Fig. 1) indicated that the first two factors were above the point of inflection, while the third factor was at the break between the slope of the first two factors and the slope of the remaining factors, with an eigenvalue of 1.02. The most critical decision after factor extraction is determining the number of factors to retain. Extracting too few or too many factors can lead to incorrect conclusions in the analysis [38, 39, 40]. Horn [41] proposed a method based on generating random variables, known as parallel analysis, to decide the number of factors to retain.

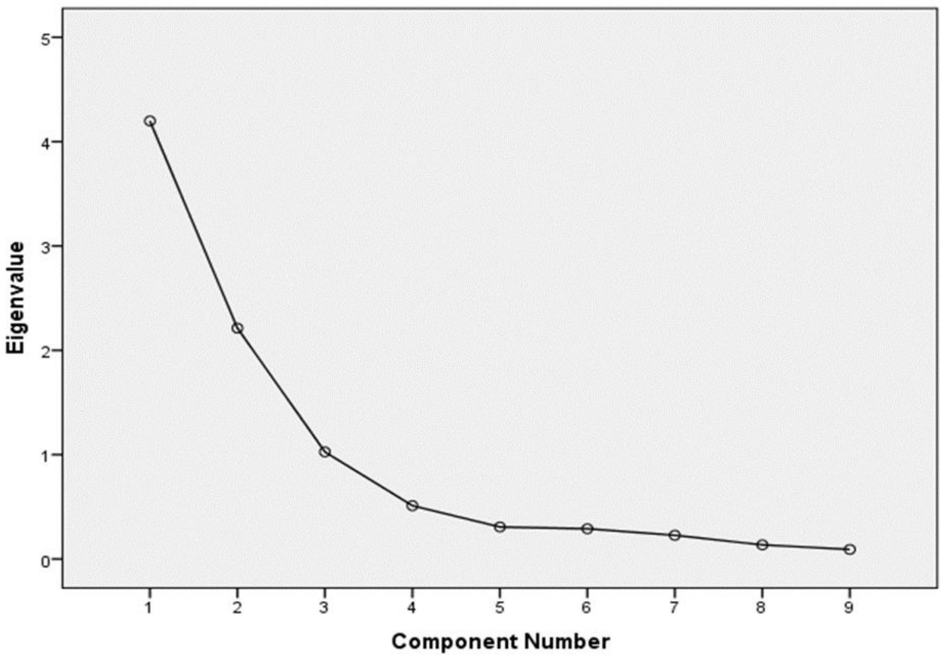

Figure 1: « Scree Chart »

Parallel analysis compares the eigenvalues of the real data to those of randomly generated data [23]. For a factor to be retained, its actual eigenvalue must be greater than the corresponding random eigenvalue. However, the parallel analysis showed that this factor could not be considered valid because its random eigenvalue (1.35) was greater than its actual eigenvalue (1.02) (Table 3). Therefore, the third extracted factor was rejected, and the PCA was repeated, fixing the number of factors at two (Table 4). The "scree plot" (Fig. 1) supports the decision to focus on only the two components mentioned. The internal consistency of the items within the extracted factors was evaluated using Cronbach's alpha. In this study, the Cronbach's alpha values were greater than 0.70 for both factors, indicating good internal consistency for F1 and F2.

F1 accounted for approximately 46.65% of the variation in the performance indicators. It had a high positive loading from four variables: mid-thigh girth (0.867), body fat percentage (0.851), thigh girth (0.848), and calf girth (0.825). These indicators are associated with body composition, which has been shown to be predictive in identifying players with specific sizes and shapes that may be suited to various positions [42]. Elite soccer teams are often characterized by a relative variation in body size [9].

F2 comprised four parameters: lower limb length (0.896), height (0.782), sitting height (0.773), and thigh length (0.736). According to Pedretti et al. [42] and Abdullah et al. [9], achieving favorable results in soccer depends on certain physical characteristics. Physical attributes in soccer are the most likely indicators for positional roles, with taller players often being better suited for central defensive positions and offensive roles among forwards or strikers [43, 44]. F2 may be linked to the early selection of players for key positions, where body size offers an advantage over technical skills. A study involving 65 elite Danish players found that goalkeepers and central defenders were the tallest and heaviest, while the mean height and body mass of full-backs, midfielders, and forwards were similar.

The findings of this study are consistent with those of Ostrowska et al. [10], who conducted research on 80 young swimmers (12 ± 0.27 years). In their study, the somatic traits were classified into two factors: the vertical dimension factor and the cubic content factor. The vertical dimension factor included body weight, Rohrer index, circumferences of the calf, forearm, chest, waist, and limb length, while the cubic content factor consisted of body height and upper and lower extremity lengths. In a more recent study by Abdullah et al. [9] involving 84 elite youth male soccer players (15.48 ± 1.47 years), the PCA identified seven factors, two of which could be described as vertical dimension and cubic content factors. The cubic content factor exhibited positive factor loadings from body weight (0.637), biceps (0.859), triceps (0.769), subscapular (0.847), suprailiac (0.886), and medial upper arm circumference (0.776). The second factor had high positive loadings from two subsets: height (0.849) and sitting height (0.873). The differences in factor structures between our study, Abdullah et al. [9], and Ostrowska et al. [10] could be attributed to variations in the measured biometric indices. In our study, only the most commonly used biometric indices were measured for practical purposes.

According to George and Mallery [46], once a factor structure has been established, it is crucial to identify which variables constitute each factor. Factor loading is used to determine the importance of each variable to a given factor [47]. Generally, an absolute value of more than 0.3 is considered significant [46]. However, the significance of a factor loading depends on the sample size. Maravelakis [47] proposed a table of critical values for comparing loadings. For a sample size of 50, as in our study (59 players), a loading of 0.722 is considered significant. In this study, all indicators with factor loadings below 0.722 were excluded. For example, body mass was excluded from the F1 structure, even though its factor loading (0.713) was greater than 0.70.

Practical Application

The current results should be used for assessing training progress and making adjustments, as well as for player selection and talent identification. The findings could provide insights into the profile of 16-year-old youth soccer players.

Limitations of the Study

This study has several methodological limitations that should be discussed. First, the results are specific to a single soccer academy and may not be generalizable to other academy settings. Other limitations include the inability to examine the influence of playing positions and the lack of data on female soccer players. Future research should focus on a larger sample size across multiple age groups and different soccer academies.

Conclusion

This study aimed to identify key anthropometric characteristics that significantly differentiate young male soccer players. A total of 59 young male players participated in this study. PCA was used to determine the most critical biometric variables. After Varimax rotation, two factors were extracted. Each component included variables selected based on their higher factor loadings. F1 had strong positive loadings from mid-thigh girth, body fat percentage, thigh girth, and calf girth, while F2 comprised lower limb length, height, sitting height, and thigh length. These findings should be utilized for assessing progress following training modifications and for player selection.

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Ethics statement

This study was reviewed and approved by the Institute's Committee on Research for the Medical Sciences (La Manouba University Ethics Committee) and performed by the current national laws and regulations and the Declaration of Helsinki. Informed consent was gained from all participants and their parents or guardians after a verbal and written explanation of the experimental protocol and its potential risks and benefits. Participants were assured that they could withdraw from the trial without penalty at any time.

Disclosure statement

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