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# Kinanthropometry and Anatomical Body Composition of Elite Soccer Players in Argentina: The FUTREF Project

**Francis Holway [1], Francesco Campa [2,*], Cristian Petri [3,4], Matteo Pincella [5,6], Pablo Ortega Gallo [7], Fabricio Forchino [8], Donald Kirkendall [9]**

[1] Departamento de Medicina, Club Atlético River Plate, Avenida Figueroa Alcorta 7597, Buenos Aires, Argentina
[2] Department of Biomedical Sciences, University of Padua, 35131 Padova, Italy.
[3] Section of Physical Education and Sport, Department of Sport and Informatics, Pablo de Olavide University, 1013 Sevilla, Spain
[4] A.C.F. Fiorentina S.r.l., 50137 Florence, Italy
[5] Inter FC, Milan, Italy
[6] FIGC Federazione Italiana Giuoco Calcio (Italian Football Federation), Rome, Italy
[7] Departamento de Medicina, Club Atlético Boca Juniors, Buenos Aires, Argentina
[8] Aspetar - Qatar Orthopaedic and Sports Medicine Hospital, Doha, Qatar
[9] FIFA Medical Commission, United States.
* Corresponding authors email: francesco.campa@unipd.it
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## Resumen

**Introducción:** Las referencias antropométricas para el deporte permiten a los investigadores y profesionales de la nutrición deportiva evaluar con precisión la composición corporal de una manera económica y eficiente. El objetivo de este estudio fue proporcionar un perfil antropométrico extenso de jugadores de fútbol de élite dividido por posición de juego. En el proyecto FUTREF participaron setecientos cincuenta y dos jugadores (edad 24,0 ± 4,4 años) de 18 equipos argentinos diferentes, medidos según el protocolo definido por la Sociedad Internacional para el Avance de la Cineantropometría (ISAK). Métodos: Se informaron parámetros antropométricos brutos y se utilizaron para calcular los componentes del somatotipo y la masa corporal según modelos moleculares (dos componentes) y anatómicos (cinco componentes). Resultados: Se identificaron diferencias estadísticamente significativas (p>0,01) para los parámetros antropométricos entre las diferentes posiciones de juego y entre jugadores seleccionados y no seleccionados para la selección absoluta. Se proporcionaron los percentiles 5, 25, 50, 75 y 95 para la relación músculo-hueso. Además, el uso de diferentes ecuaciones mostró diferentes resultados en la predicción de la composición corporal. Conclusión: Este estudio proporciona datos antropométricos de referencia para evaluar la composición corporal en jugadores de fútbol de élite.

**Palabras Clave:** Antropometría, Composición corporal, Masa muscular, Relación músculo-hueso, Fútbol

**Abstract:** Introduction: Anthropometric references for sports enable researchers and sports nutrition professionals to accurately assess body composition in an economical and efficient manner. The objective of this study was to provide an extensive anthropometric profile of elite soccer players divided by playing position. Seven hundred fifty-two players (age 24.0 ± 4.4 years) from 18 different Argentine teams were involved in the FUTREF project and measured according to the protocol defined by the International Society for the Advancement of Kinanthropometry (ISAK). Methods: Raw anthropometric parameters were reported and used to calculate somatotype and body mass components according to molecular (two-components) and anatomical (five-components) models. Results: Statistically significant differences (p>0.01) were identified for anthropometric parameters among different playing positions and between players selected and not selected for the senior national team. The 5th, 25th, 50th, 75th, and 95th percentiles for the muscle-to-bone ratio were provided. Furthermore, the use of different equations showed different outputs in predicting body composition. Conclusion: This study provides anthropometric reference data for evaluating body composition in elite soccer players.

Keywords: Anthropometry, Body composition, Muscle mass, Muscle-to-Bone-ratio, Football

## Introduction

Soccer is an intermittent sport that stresses both the anaerobic and aerobic systems of players (Collins et al., 2021). There are marked differences in positional roles regarding game-specific tasks and physical demands, which consequently lead to variations in body morphology (Campa et al., 2023, 2020). or instance, physiological capacity is closely related to player position: midfielders and fullbacks exhibit the largest maximal oxygen capacity but also the lowest levels of muscle strength (Reilly et al., 2000). These physical attributes typically manifest in the size and composition of different positions, with goalkeepers being the tallest and heaviest, and midfielders displaying the lowest levels of body fat (Carling and Orhant, 2010).

Sports medicine professionals and trainers often assess their players' physiological and anthropometric characteristics against elite references to evaluate strengths and weaknesses (Brocherie et al., 2014; Holway and Garavaglia, 2009; Shahidi et al., 2023). This underscores the importance of updated databases of elite athletes. Furthermore, in team sports, the distinct positional tasks and morphology necessitate position-specific references. However, current published anthropometric data on elite soccer players often aggregate specific positions into broader categories to achieve statistical power for analysis, potentially obscuring important inter-position differences. For example, fullbacks are generally smaller than center backs, yet their data is often summarized together as "backs". Other shortcomings in published reports for field-based practitioners include the limited scope of presented anthropometric information, often restricted to height, weight, and sometimes body fat (Reilly et al., 2009), non-standardized measuring protocols, and a low number of subjects tested to establish references.

While skinfolds and percentage body fat serve as useful indicators of adiposity, quantifying muscle mass is particularly intriguing, as it is this tissue that drives movement in sports (Campa et al., 2021). Utilizing anatomical fractionation models to assess body composition can provide insights into adipose and muscle mass, as well as skeletal and residual masses (organs and viscera) (Campa et al., 2021; Wong et al., 2023). Therefore, our objective is to present position-specific detailed anthropometric and body fractionation data for a large cohort of elite soccer players using standardized measuring techniques.

## Methods

Eighteen elite professional soccer teams from the Argentine Football Association (AFA) first division league, together with 27 Argentine national team members playing in European clubs, were measured. For comparison against a normal population sample, we measured a fitness-oriented reference sample (ARGOREF), made up of 87 twenty-to-thirty-year-old healthy males who engage in regular physical activity randomly selected from fitness centers in the Buenos Aires metropolitan area. Measurements were taken by eighteen experienced International Society for the Advancement of Kinanthropometry (ISAK)-certified levels 2, 3, and 4 anthropometrists in a collaborative effort to standardize measurements and build databases (International Society for Advancement of Kinanthropometry., 2001). Variables include body mass, height, sitting height, ten limb and torso girths, six bone breadths, and six skinfolds. Equipment consisted of CAM mechanical (CAM, Argentina) or ASPEN EB6571 (Zhongshan Jinli Electronic, China) digital scales, wall-mounted portable stadiometers, 50-cm wooden boxes for sitting height, Lufkin WP606 and Anthrotape (Rosscraft, Canada) measuring tapes, Campbell 10 and 20 small and large bone breadth calipers (Rosscraft SRL, Argentina), and Harpenden (Baty, UK), and Slim Guide (CHP, USA) skinfold calipers. Measurements were collected as part of regular pre-season or in-season evaluations, with all subjects agreeing to the protocol and posterior later use for reference-database building. Approval for the study was obtained from the Ethics Committee of the Medical Department at River Plate. Field data collected with proformas were entered into spreadsheets, checked for errors and inconsistencies, and later entered into the ISAK metry software (International Society for Advancement of Kinanthropometry., 2001) for the calculations of: i) five-way anatomical body fractionation (Ross and Kerr, 1993) ii) somatotype, and iii) selected indices: sum of six skinfolds (∑6skf), body mass index, muscle-to-bone-ratio, and skinfold-corrected girths. In order to show the differences between body composition methods, body fat was calculated using the Reilly (Reilly et al., 2009) and Lohman (Lohman et al., 1988) equations, and muscle mass with the Martin (Martin et al., 1990) and Lee (Lee et al., 2000) formulas. Players were grouped into their specific positions, defined as goalkeepers, central defenders, lateral defenders, defensive midfielders, midfielders, offensive midfielders, and forwards. Players were also classified as having been or not selected for the National Argentine Team, as shown in Table 1.

### Statistical analysis

Data were analyzed with SPSS v. 29.0 (SPSS, IBM Corp., Chicago, IL, USA). The normal distribution of the investigated variables was assessed using the Shapiro-Wilks Test. Strudent t-test for independent samples and oneway analysis of variance (ANOVA) were performed for comparing body composition between players. Statistical significance was set at $p < 0.05$.

**Table 1.** Soccer positional nomenclature with approximate equivalences in other languages

| Basic | English | Argentine | Spanish (Argentina) | Portuguese (Brazil) |
|---|---|---|---|---|
| Goalkeeper | Keeper | Goalkeeper | Arquero | Goleiro |
| Defender | Centre Back | Central Defender | Defensor Central | Zagueiro |
| | Full Back | Lateral Defender | Defensor Lateral | Lateral |
| | | | | |
| Midfield | Centre Midfield | Defensive Midfield | Volante Central | Volante |
| | | Side Midfielder | Volante/Carrilero | |
| | | Offensive Midfield | Enganche | Meia |
| Forward | Centre Forward | Forward | Delantero | Atacante |
| | Winger | | | |

## Results

Tables 2 and 3 provide descriptive information of all anthropometric variables measured, body composition, somatotype, and selected indices per playing position. Somatotype features are shown in Figure 1, while Figure 2 reports body mass components estimated at different levels. All variables from both these tables were statistically significantly different between playing positions ($p<0.01$), with the exception of age ($p=0.018$), skeletal mass % ($p=0.017$), and muscle-to-bone ratio ($p=0.068$).

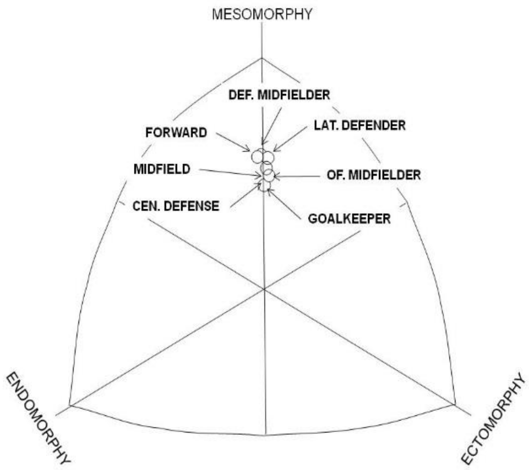


**Figure 1.** Somatochart with the soccer players grouped by position

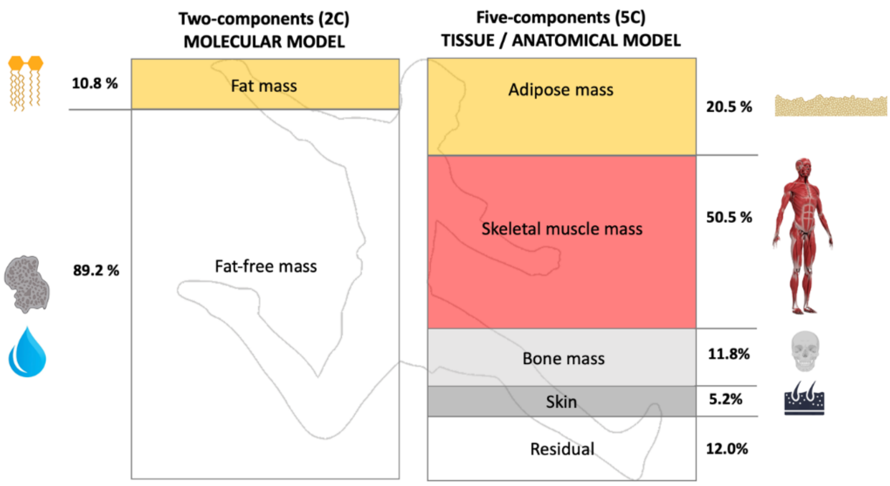


**Figure 2.** Reference values estimated at different body composition levels in the soccer players

**Table 2.** Descriptive anthropometric characteristics of elite Argentine soccer players by position (mean ± standard deviation).

| | GOALKEEPER | CENTRAL DEFENDER | LATERAL DEFENDER | DEFENSIVE MIDFIELD | SIDE MIDFIELD | OFFENSIVE MIDFIELD | FORWARD | TOTAL |
|---|---|---|---|---|---|---|---|---|
| | (*n* = 81) | (*n* = 124) | (*n* = 113) | (*n* =59) | (*n* = 174) | (*n* = 50) | (*n* = 151) | (*n* = 752) |
| **Basics** | | | | | | | | |
| Age (years) | 25.3 ± 5.0 | 23.7 ± 4.2 | 24.1 ± 4.2 | 25.0 ± 4.0 | 23.9 ± 3.9 | 22.6 ± 3.4 | 23.8 ± 5.0 | 24.0 ± 4.4 |
| Body mass (kg) | 83.7 ± 5.9 | 80.8 ± 5.1 | 73.5 ± 5.7 | 75.7 ± 5.0 | 74.3 ± 5.7 | 71.6 ± 7.8 | 78.4 ± 7.2 | 77.1 ± 7.0 |
| Stature (cm) | 185.4 ± 4.4 | 182.8 ± 4.6 | 175.4 ± 4.6 | 177.7 ± 5.6 | 176.5 ± 4.9 | 173.2 ± 7.3 | 178.7 ± 6.0 | 178.7 ± 6.3 |
| Sitting height (cm) | 96.5 ± 2.5 | 95.9 ± 3.0 | 92.6 ± 2.7 | 94.0 ± 3.3 | 92.7 ± 3.0 | 92.1 ± 3.2 | 93.9 ± 3.5 | 93.9 ± 3.4 |
| **Breadths (cm)** | | | | | | | | |
| Biacromiale | 42.1 ± 1.6 | 41.5 ± 1.8 | 40.0 ± 1.9 | 41.0 ± 1.7 | 40.3 ± 1.8 | 39.9 ± 2.0 | 40.9 ± 1.8 | 40.8 ± 1.9 |
| Transverse chest | 30.5 ± 1.7 | 30.1 ± 1.5 | 29.2 ± 1.8 | 29.2 ± 1.7 | 29.0 ± 1.6 | 28.7 ± 1.6 | 29.8 ± 1.5 | 29.5 ± 1.7 |
| Antero-post. chest | 21.3 ± 1.4 | 20.7 ± 1.3 | 20.2 ± 1.6 | 20.5 ± 1.4 | 20.2 ± 1.5 | 20.2 ± 1.3 | 20.7 ± 1.4 | 20.5 ± 1.5 |
| Bi-cristale | 29.3 ± 1.5 | 29.0 ± 1.5 | 27.9 ± 1.4 | 28.3 ± 1.2 | 28.1 ± 1.4 | 27.8 ± 1.4 | 28.6 ± 1.5 | 28.4 ± 1.5 |
| Humerus | 7.4 ± 0.3 | 7.3 ± 0.3 | 7.0 ± 0.4 | 7.2 ± 0.3 | 7.0 ± 0.3 | 7.0 ± 0.4 | 7.2 ± 0.4 | 7.1 ± 0.4 |
| Femur | 10.4 ± 0.4 | 10.4 ± 0.4 | 10.0 ± 0.4 | 10.1 ± 0.4 | 10.0 ± 0.4 | 10.0 ± 0.5 | 10.2 ± 0.5 | 10.2 ± 0.4 |
| **Girths (cm)** | | | | | | | | |
| Head | 57.3 ± 1.4 | 57.0 ± 1.4 | 56.5 ± 1.5 | 56.8 ± 1.3 | 56.4 ± 1.3 | 56.3 ± 1.3 | 56.9 ± 1.3 | 56.7 ± 1.4 |
| Arm, relaxed | 31.9 ± 1.6 | 30.6 ± 1.5 | 30.0 ± 1.7 | 30.1 ± 1.3 | 29.7 ± 1.6 | 29.7 ± 1.8 | 30.7 ± 1.8 | 30.4 ± 1.8 |
| Arm, flexed | 34.4 ± 1.6 | 33.3 ± 1.5 | 32.5 ± 1.8 | 32.6 ± 1.3 | 32.1 ± 1.6 | 32.0 ± 1.6 | 33.2 ± 1.8 | 32.9 ± 1.8 |
| Forearm | 28.5 ± 1.1 | 27.7 ± 1.0 | 27.0 ± 1.2 | 27.2 ± 1.1 | 26.9 ± 1.2 | 26.8 ± 1.5 | 27.7 ± 1.5 | 27.4 ± 1.3 |
| Chest, meso-ster. | 101.8 ± 3.9 | 99.1 ± 3.6 | 96.9 ± 4.1 | 97.8 ± 3.6 | 96.6 ± 4.0 | 95.3 ± 4.0 | 98.7 ± 4.1 | 98.1 ± 4.3 |
| Waist, minimun | 82.4 ± 3.8 | 81.3 ± 3.4 | 79.5 ± 3.7 | 80.3 ± 3.3 | 79.5 ± 3.6 | 78.7 ± 4.2 | 81.5 ± 3.9 | 80.5 ± 3.8 |
| Glueteal, maximun | 101.0 ± 3.8 | 99.4 ± 3.4 | 95.9 ± 3.4 | 97.4 ± 2.8 | 96.5 ± 3.8 | 95.3 ± 4.2 | 98.4 ± 4.3 | 97.8 ± 4.1 |
| Upper thigh | 59.8 ± 2.5 | 59.8 ± 2.5 | 57.8 ± 2.5 | 58.6 ± 2.0 | 57.7 ± 2.6 | 57.3 ± 3.3 | 59.0 ± 3.0 | 58.6 ± 2.8 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mid-thigh | 55.4 ± 2.5 | 55.9 ± 2.2 | 54.2 ± 2.5 | 55.0 ± 2.1 | 54.1 ± 2.6 | 53.7 ± 3.1 | 55.4 ± 2.9 | 54.9 ± 2.7 |
| Calf, maximun | 38.3 ± 2.0 | 38.6 ± 1.5 | 37.2 ± 1.7 | 37.7 ± 1.6 | 37.4 ± 1.9 | 36.9 ± 2.0 | 38.2 ± 2.1 | 37.8 ± 1.9 |
| **Skinfolds (mm)** | | | | | | | | |
| Triceps | 8.7 ± 2.7 | 8.3 ± 2.8 | 7.2 ± 2.3 | 7.5 ± 2.4 | 7.6 ± 2.1 | 7.6 ± 2.9 | 7.8 ± 2.7 | 7.8 ± 2.6 |
| Subscapulare | 9.5 ± 2.0 | 8.7 ± 2.5 | 8.3 ± 1.9 | 8.1 ± 1.6 | 8.6 ± 1.8 | 8.4 ± 1.7 | 9.0 ± 2.3 | 8.7 ± 2.1 |
| Supraspinale | 7.5 ± 2.7 | 6.8 ± 2.6 | 6.1 ± 1.9 | 6.1 ± 1.7 | 6.5 ± 2.2 | 6.7 ± 2.5 | 6.9 ± 3.0 | 6.7 ± 2.4 |
| Abdominale | 15.0 ± 5.8 | 12.7 ± 5.5 | 11.1 ± 4.5 | 11.3 ± 4.3 | 12.2 ± 5.0 | 12.1 ± 5.2 | 13.5 ± 6.7 | 12.6 ± 5.6 |
| Fronth thigh | 10.6 ± 3.7 | 9.5 ± 3.0 | 8.6 ± 2.9 | 8.7 ± 2.4 | 8.7 ± 2.5 | 8.9 ± 3.2 | 9.2 ± 3.4 | 9.1 ± 3.1 |
| Medial calf | 6.7 ± 2.6 | 6.0 ± 1.9 | 5.3 ± 1.8 | 5.2 ± 1.5 | 5.7 ± 1.6 | 5.8 ± 2.2 | 5.8 ± 1.9 | 5.8 ± 1.9 |

**Table 3.** Body composition, somatotype, and selected indices of elite Argentine soccer players by position (mean ± standard deviation).

| | GOALKEEPER | CENTRAL DEFENDER | LATERAL DEFENDER | DEFENSIVE MIDFIELD | SIDE MIDFIELD | OFFENSIVE MIDFIELD | FORWARD | TOTAL |
|---|---|---|---|---|---|---|---|---|
| | (*n* = 81) | (*n* = 124) | (*n* = 113) | (*n* =59) | (*n* = 174) | (*n* = 50) | (*n* = 151) | (*n* = 752) |
| **Adipose** | | | | | | | | |
| (%) | 22.6 ± 2.9 | 21.5 ± 2.8 | 20.2 ± 2.6 | 20.3 ± 2.1 | 20.9 ± 2.4 | 20.7 ± 3.0 | 20.9 ± 2.8 | 21.0 ± 2.7 |
| (kg) | 18.9 ± 2.8 | 17.5 ± 2.6 | 14.9 ± 2.3 | 15.3 ± 1.9 | 15.6 ± 2.3 | 14.9 ± 2.9 | 16.5 ± 3.2 | 16.3 ± 2.9 |
| **Muscle** | | | | | | | | |
| (%) | 49.5 ± 2.5 | 49.9 ± 2.3 | 50.9 ± 2.1 | 50.6 ± 1.9 | 50.1 ± 2.1 | 50.0 ± 2.3 | 50.4 ± 2.3 | 50.2 ± 2.2 |
| (kg) | 41.5 ± 3.6 | 40.5 ± 3.2 | 37.5 ± 3.3 | 38.2 ± 2.9 | 37.3 ± 3.4 | 35.8 ± 4.3 | 39.5 ± 3.5 | 38.7 ± 3.8 |
| **Residual** | | | | | | | | |
| (%) | 11.6 ± 0.8 | 11.8 ± 0.8 | 12.1 ± 0.8 | 12.0 ± 0.7 | 11.9 ± 0.7 | 12.1 ± 0.8 | 12.0 ± 0.8 | 11.9 ± 0.8 |
| (kg) | 9.7 ± 1.0 | 9.6 ± 0.9 | 8.9 ± 0.9 | 9.1 ± 0.8 | 8.9 ± 0.9 | 8.6 ± 1.0 | 9.4 ± 0.9 | 9.2 ± 1.0 |
| **Skeletal** | | | | | | | | |
| (%) | 11.3 ± 0.9 | 11.6 ± 0.9 | 11.6 ± 0.8 | 11.9 ± 0.7 | 11.7 ± 0.9 | 11.9 ± 0.8 | 11.6 ± 0.8 | 11.6 ± 0.9 |
| (kg) | 9.5 ± 0.9 | 9.4 ± 0.8 | 8.5 ± 0.8 | 8.9 ± 0.7 | 8.7 ± 0.8 | 8.5 ± 0.9 | 9.1 ± 0.9 | 9.0 ± 0.9 |
| **Skin** | | | | | | | | |
| (%) | 5.0 ± 0.2 | 5.1 ± 0.2 | 5.3 ± 0.3 | 5.2 ± 0.2 | 5.3 ± 0.3 | 5.3 ± 0.3 | 5.1 ± 0.3 | 5.2 ± 0.3 |

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (kg) | 4.2 | ± | 0.2 | 4.1 | ± | 0.2 | 3.9 | ± | 0.2 | 3.9 | ± | 0.2 | 3.9 | ± | 0.2 | 3.8 | ± | 0.3 | 4.0 | ± | 0.2 | 4.0 | ± | 0.3 |
| **Error** | | | | | | | | | | | | | | | | | | | | | | | | |
| (%) | 3.0 | ± | 3.7 | 1.3 | ± | 3.2 | 1.0 | ± | 2.8 | 1.5 | ± | 2.8 | 0.6 | ± | 3.4 | 1.2 | ± | 2.6 | 1.3 | ± | 3.6 | 1.3 | ± | 3.3 |
| (kg) | 2.5 | ± | 3.1 | 1.0 | ± | 2.6 | 0.7 | ± | 2.1 | 1.1 | ± | 2.1 | 0.5 | ± | 2.5 | 0.9 | ± | 1.9 | 1.1 | ± | 2.9 | 1.0 | ± | 2.6 |
| **Somatotype** | | | | | | | | | | | | | | | | | | | | | | | | |
| Endomorphy | 2.6 | ± | 0.7 | 2.4 | ± | 0.7 | 2.1 | ± | 0.6 | 2.1 | ± | 0.5 | 2.2 | ± | 0.6 | 2.2 | ± | 0.7 | 2.3 | ± | 0.8 | 2.3 | ± | 0.7 |
| Mesomorphy | 5.2 | ± | 0.8 | 5.3 | ± | 0.7 | 5.4 | ± | 0.8 | 5.4 | ± | 0.8 | 5.3 | ± | 0.8 | 5.5 | ± | 1.0 | 5.5 | ± | 0.8 | 5.4 | ± | 0.8 |
| Ectomorphy | 2.5 | ± | 0.6 | 2.4 | ± | 0.6 | 2.1 | ± | 0.6 | 2.2 | ± | 0.7 | 2.2 | ± | 0.7 | 2.0 | ± | 0.8 | 2.0 | ± | 0.7 | 2.2 | ± | 0.7 |
| **Indices** | | | | | | | | | | | | | | | | | | | | | | | | |
| BMI ($kg*m^{-2}$) | 24.3 | ± | 1.3 | 24.2 | ± | 1.2 | 23.9 | ± | 1.3 | 23.9 | ± | 1.1 | 23.9 | ± | 1.5 | 23.8 | ± | 1.7 | 24.5 | ± | 1.5 | 24.1 | ± | 1.4 |
| Σ 6 skinfolds (mm) | 58.5 | ± | 14.7 | 52.6 | ± | 14.8 | 46.9 | ± | 12.0 | 47.3 | ± | 9.8 | 49.3 | ± | 11.9 | 49.5 | ± | 14.3 | 52.2 | ± | 16.7 | 50.9 | ± | 14.2 |
| Muscle · bone ratio$^{-1}$ | 4.40 | ± | 0.44 | 4.32 | ± | 0.42 | 4.42 | ± | 0.37 | 4.28 | ± | 0.32 | 4.30 | ± | 0.42 | 4.24 | ± | 0.33 | 4.37 | ± | 0.36 | 4.34 | ± | 0.40 |

**Table 4.** Fat, adipose and muscle mass estimated with different anthropometric equations in soccer players grouped by roles.

| | GOALKEEPER | | | CENTRAL DEFENDER | | | LATERAL DEFENDER | | | DEFENSIVE MIDFIELD | | | SIDE MIDFIELD | | | OFFENSIVE MIDFIELD | | | FORWARD | | | TOTAL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (n = 81) | | | (n = 124) | | | (n = 113) | | | (n =59) | | | (n = 174) | | | (n = 50) | | | (n = 151) | | | (n = 752) | | |
| Adipose Kerr[1] (%) | 22.6 | ± | 2.9 | 21.5 | ± | 2.8 | 20.2 | ± | 2.6 | 20.3 | ± | 2.1 | 20.9 | ± | 2.4 | 20.7 | ± | 3.0 | 20.9 | ± | 2.8 | 21.0 | ± | 2.7 |
| Body fat Reilly[2] (%) | 11.3 | ± | 1.7 | 10.7 | ± | 1.7 | 10.0 | ± | 1.4 | 10.1 | ± | 1.1 | 10.3 | ± | 1.3 | 10.3 | ± | 1.7 | 10.6 | ± | 1.9 | 10.5 | ± | 1.6 |
| Body fat Lohman[3] (%) | 12.7 | ± | 3.3 | 11.4 | ± | 3.7 | 10.2 | ± | 2.8 | 10.2 | ± | 2.4 | 10.8 | ± | 2.9 | 10.7 | ± | 3.1 | 11.5 | ± | 4.1 | 11.1 | ± | 3.4 |
| Muscle Kerr[4] (kg) | 41.5 | ± | 3.6 | 40.5 | ± | 3.2 | 37.5 | ± | 3.3 | 38.2 | ± | 2.9 | 37.3 | ± | 3.4 | 35.8 | ± | 4.3 | 39.5 | ± | 3.5 | 38.7 | ± | 3.8 |
| Muscle Martin[5] (kg) | 47.4 | ± | 6.7 | 46.5 | ± | 7.6 | 43.5 | ± | 4.0 | 44.8 | ± | 3.8 | 41.7 | ± | 8.1 | 39.9 | ± | 8.4 | 44.9 | ± | 7.4 | 44.1 | ± | 7.3 |
| Muscle Lee[6] (kg) | 36.7 | ± | 2.6 | 35.9 | ± | 2.1 | 33.7 | ± | 2.2 | 34.1 | ± | 2.2 | 33.6 | ± | 2.2 | 32.8 | ± | 2.7 | 35.2 | ± | 2.5 | 34.6 | ± | 2.6 |

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Figure 3 depicted the percentiles (5th, 25th, 50th, 75th, and 95th) for the muscle-to-bone ratio. Table 4 shows body composition data estimated by different equations on the soccer players.

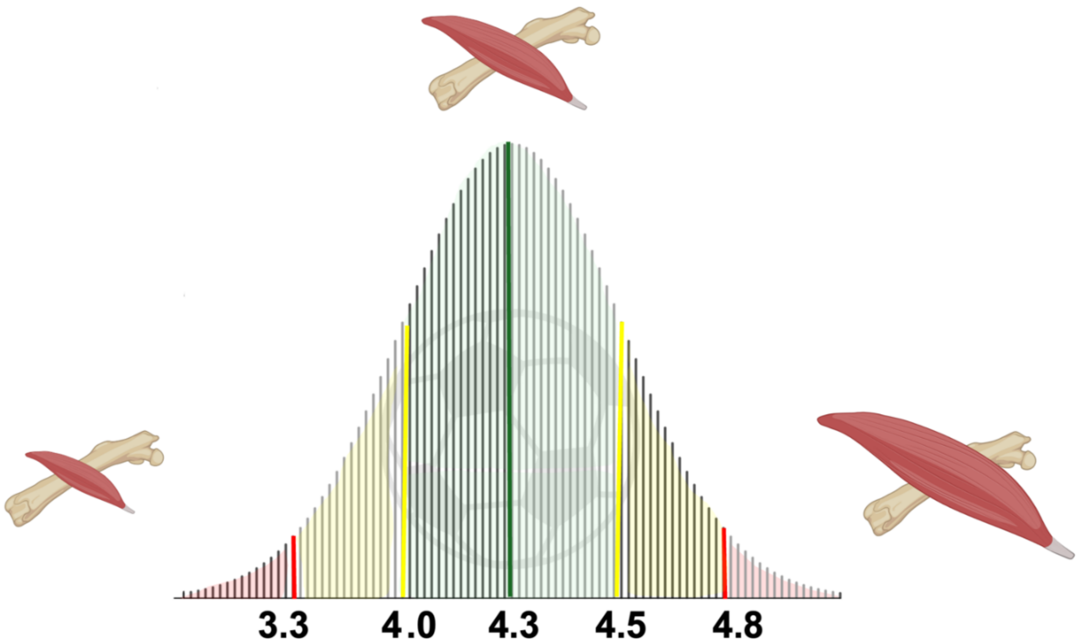


**Figure 3.** The 5th, 25th, 50th, 75th, and 95th reference percentiles for muscle-to-bone ratio in the soccer players

In Table 5 the soccer players are compared to a reference sample and are found to be taller, heavier, leaner, and to have similar arm but larger thigh and calf muscle development, as determined with skinfold-corrected girths at the mentioned sites. There were no statistically significant differences between selected and non-selected players in size and body composition (Table 6), although selected players were 1.4 years older (p = 0.004).

**Table 5.** Comparison of Argentine soccer players against a fitness-oriented normal reference sample (ARGOREF). Values are presented as mean ± standard deviation

| VARIABLE | Current study | | | ARGOREF | | | Diff. | *p* |
|---|---|---|---|---|---|---|---|---|
| | n = 752 | | | n = 87 | | | | |
| Body mass, kg | 77.1 | ± | 7.0 | 74.7 | ± | 9.0 | 2.4 | 0.018 |
| Height, cm | 178.7 | ± | 6.3 | 175.4 | ± | 7.3 | 3.3 | <0.001 |
| Corrected arm girth, cm | 27.9 | ± | 1.7 | 28.3 | ± | 2.6 | -0.4 | 0.189 |
| Corrected thigh girth, cm | 55.7 | ± | 2.6 | 53.5 | ± | 2.8 | 2.3 | <0.001 |
| Corrected calf girth, cm | 36.0 | ± | 1.9 | 35.0 | ± | 2.1 | 1.0 | <0.001 |
| Σ 6 skinfolds, mm | 50.7 | ± | 14.1 | 67.5 | ± | 24.5 | -16.8 | <0.001 |

**Table 6.** Comparison of selected against non-selected soccer players. Values are presented as mean ± standard deviation

| VARIABLE | SELECTED | | | NON-SELECTED | | | Diff. | *p* |
|---|---|---|---|---|---|---|---|---|
| | n = 91 | | | n = 661 | | | | |
| Age, years | 25.2 | ± | 4.3 | 23.9 | ± | 4.3 | 1.4 | |
| Body mass, kg | 77.4 | ± | 6.0 | 77.0 | ± | 7.2 | 0.4 | 0.594 |
| Height, cm | 179.0 | ± | 6.0 | 178.6 | ± | 6.3 | 0.3 | 0.629 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Adipose, % | 20.5% | ± | 2.5% | 21.0% | ± | 2.8% | -0.6% | 0.065 |
| Muscle, % | 50.5% | ± | 2.2% | 50.2% | ± | 2.2% | 0.3% | 0.245 |
| Residual, % | 12.0% | ± | 0.7% | 12.0% | ± | 0.8% | 0.1% | 0.113 |
| Skeletal, % | 11.8% | ± | 1.0% | 11.6% | ± | 0.8% | 0.1% | 0.201 |
| Skin, % | 5.2% | ± | 0.3% | 5.2% | ± | 0.3% | 0.0% | 0.807 |

## Discussion

The aim of the present article was to provide comprehensive and detailed kinanthropometric standards stratified by specific playing positions. Considering the soccer players grouped by roles, central defenders (centre backs) exhibited significant differences from lateral defenders (fullbacks): they were 7.2 cm taller, 7.3 kg heavier, and possessed 2.6 kg more adipose and 3.0 kg more muscle tissue ($p < 0.001$ for all variables). Both defending positions had a standard deviation for height of 4.6 cm. However, if grouped together, this variation would have increased to 5.8 cm, obscuring the distinctions between them and diminishing our analytical capacity. As anticipated, goalkeepers were the tallest, while offensive midfielders were the shortest. The size of the soccer goal necessitated a tall individual for effective defense, whereas superior skill and agility were often associated with shorter individuals with shorter lever arms, such as the playmaker, who created scoring opportunities for the forwards. The considerable variation in the height of forwards (standard deviation of 6.0 cm) reflected two distinct biotypes of players commonly observed in Argentine soccer: the tall ball-header and the short dribbler. Our data are similar to those reported in a recent study on elite soccer players playing in Italy and measured using the same anthropometric standards (Petri et al., 2024).

The five-way fractionation method of analyzing body composition enables to interpret tissue masses from three perspectives: a) as a fraction of total body mass (expressed as %), b) in absolute terms (expressed as kg), and c) in proportion to height (expressed as Phantom-z scores). The calculation of adipose mass, for instance, included the sum of six skinfolds and height, since adipose tissue is a three-dimensional entity (Heymsfield et al., 2005). This was particularly useful when comparing individuals of different heights and sizes, such as central defenders (182.8 ± 4.6 cm) and offensive midfielders (173.2 ± 6.0 cm). These defenders had 2.6 kg more adipose mass and 0.8% more body mass-relative adipose % but were practically identical relative to height (1.93 against 1.95 phantom-z scores). Regarding muscle, central defenders had 4.7 kg more absolute muscle mass, similar % muscle (49.9% against 50.0%), but were less muscular relative to height (1.59 against 1.83 Phantom-z scores). Offensive midfielders required a significant amount of muscle for explosive short bursts, and it would have been erroneous to conclude that they were less muscular than other players simply because they had less absolute mass. Further details of the five-way fractionation method were beyond the scope of this work but could be found elsewhere (Holway and Garavaglia, 2009).

For the purpose of providing data for professionals using other body composition methods, our data considered body fatness estimated with the Lohman (Lohman et al., 1988) and Reilly (Reilly et al., 2009) equations based on the two-compartment methods, and muscle mass with the Martin (Martin et al., 1990) and Lee (Lee et al., 2000) formulas. Upon initial examination, the adipose values of the five-way fractionation model appeared to overestimate this tissue compared to the body fat % values. It was important to note that anatomically defined adipose tissue in this model differed from the chemically-defined fat (lipid) two-compartment method, as it encompassed lipids, electrolytes, proteins, and water, resulting in larger values, approximately ten percent larger in soccer players (Martin et al., 1990).

An alternative approach for assessing fatness is to use the “Olympic” sum of six skinfolds (Robson, 1982). This approach collected fatness information from upper and lower limbs, as well as the front and back trunk, and could be immediately added together and compared to standards. The muscle-to-bone ratio, an index of muscularity relative to skeletal mass, did not show statistically significant differences between playing positions, although these soccer players had a lower value, 4.34 ± 0.40, than a sample of rugby players who had 4.58 ± 0.49, but similar to a normal sample reference which had 4.28 ± 0.49. While the muscle-to-bone ratio is valuable for assessing muscle relative to bone mass, it lacks specificity regarding muscle localization. This consideration is crucial in sports where specific muscle groups are valid predictors of performance. For instance, in soccer, calf muscle mass contributes to the ability to perform repeated sprints with changes of direction, a key test in soccer (Campa et al., 2019). Nonetheless, certain sports may prioritize overall muscle mass regardless of its distribution. In such cases, the muscle-to-bone ratio remains a valuable tool, providing insights into an athlete's potential for muscle gain based on their morphology.

As outlined by O’Connor et al. (O’Connor et al., 2007), the importance of morphological optimization could be quantified using three types of comparisons: a) between the athletic population and the source population; b) using "best vs. rest" analysis; and c) comparisons across time. Comparison between soccer players and a local reference sample revealed the footballers to be bigger in size but with less adiposity. To assess differences in regional muscularity, skinfold-corrected girths were calculated and, as expected, the soccer players were found to be more muscular in the lower limbs but similar in the arms. The comparison between selected and non-selected players showed no differences in size and body composition, although the selected players were 1.4 years older. This result coincided with the analysis performed by Reilly et al. (Reilly et al., 2000) on the anthropometric predispositions for elite soccer, where they found a relative heterogeneity in body size; however, Kalapotharakos et al. (Kalapotharakos et al., 2006) found that in the Greek league better-ranked teams had less body fat. Therefore, non-anthropometric characteristics, such as agility and skill, and perhaps experience, might have been determining factors in selecting the best players in Argentina.

## Conclusions

In conclusion, these new references can support the work of researchers and professionals interested in assessing body composition in soccer using anthropometric measurement techniques. This will allow sports science professionals to access information tools that aided in athlete profiling, training, nutritional counseling, and talent identification. Reporting descriptive data for each specific playing position represents an opportunity to cluster players into broad categories (goalkeepers, defenders, midfielders, and forwards) to facilitate multiple comparisons.

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## Conflicts of Interest

The authors have no conflicts of interest to declare that they are relevant to the content of this article.

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