Article

Not peer-reviewed version

Morphological Characteristics of Elite International Soccer Referees: Somatotype and Bioelectrical Impedance Vector Analysis

Pascal Izzicupo , Cristian Petri * , Sofia Serafini , Giorgio Galanti , Gabriele Mascherini

Posted Date: 9 June 2023

doi: 10.20944/preprints202306.0709.v1

Keywords: soccer referees; body composition; somatotype; tolerance ellipses; DXA; BIA vector

Article

Morphological Characteristics of Elite International Soccer Referees: Somatotype and Bioelectrical Impedance Vector Analysis

Pascal Izzicupo [1], Cristian Petri [2,*], Sofia Serafini [1], Giorgio Galanti [3] and Gabriele Mascherini [3]

[1] Department of Medicine and Aging Science, "G. D'Annunzio" University of Chieti-Pescara, 66100 Chieti, Italy; pascal.izzicupo@unich.it; sofiaserafini97@gmail.com
[2] Department of Sports and Computer Science, Section of Physical Education and Sports, Universidad Pablo de Olavide, 41013 Seville, Spain; cpet2@alu.upo.es
[3] Department Sports and Exercise Medicine Unit, Clinical and Experimental Department, University of Florence, 50121 Firenze, Italy; giorgio.galanti@unifi.it; gabriele.mascherini@unifi.it
* Correspondence: cpet2@alu.upo.es

Abstract: This study aimed to assess the physical characteristics of elite international soccer referees, compare them with other referee populations in the literature, and establish reference tolerance ellipses for the bioelectrical impedance vector analysis (BIVA) point graph. Forty-one elite international soccer referees (age 38.8 ± 3.6 years) participated in the study. the participants underwent body composition assessments, including dual-energy X-ray absorptiometry, BIVA, and somatotype. The Somatotype Attitudinal Distance (SAD), the two-sample Hotelling's T^2 test, and the Mahalanobis test were used to determine somatotype and bioelectrical vector differences with the literature. The average somatotype of the referees was a balanced mesomorph (2.8, 6.5, 2.8). Elite international referees significantly differed from other samples in the literature (SAD = 2.1, 2.6, 2.9 with respect to Zimbabwean, Brazilian, and South African referees, respectively). The bioelectrical vector was significantly different from the general population ($T^2 \leq 76.6$; F = 38.8; D = 1.44; P < 0.001) and athletes ($T^2 \leq 25.3$; F = 12.6; D = 0.8; P < 0.001). Somatotype values and tolerance ellipses from this study may be useful as a reference for developing training programs and improving the selection process of referees in soccer.

Keywords: soccer referees; body composition; somatotype; tolerance ellipses; DXA; BIA vector

1. Introduction

In recent years, many studies investigated the physiological and cognitive profile of soccer referees. Top-level referees generally cover a distance of 10,000-13,000 m, 10% at high intensity, and experience several accelerations at maximal or near maximal intensity [1,2]. In addition, referees must make decisions, have control of the match, and evaluate situations under intense psychological pressure [3–5]. Indeed, referees exhibit diminished cardiac autonomic control from 5 h before the match up to 10 h post-match, probably due to significant psycho-physiological stress [6]. Both the physical and mental load of football refereeing require good physical fitness, of which body composition is a crucial factor [7]. However, this aspect is still underdeveloped in the literature. For example, elite referees (FIFA) show lower body mass index (BMI) and fat mass percentage than previously reported in Premier League referees [8,9], probably due to the increasing intensity of the football matches experienced in recent years. This trend was also evident in an eleven-year retrospective study on 470 Spanish elite football referees, which reported a decrease in BMI skinfolds thickness [10]. Our recent study of 43 elite international referees found a balanced mesomorph dominant somatotype pattern [11], similar to previous findings in Zimbabwean referees [12] and in contrast to results from Brazilian [13], Chilean [14], and South African [15] referees.

Interest in bioelectrical impedance vector analysis (BIVA) has recently grown in the scientific literature [16], and references have been developed for both the general [17] and diverse populations of athletes [18–23]. However, there is a lack of BIVA studies on soccer referees. Considering the rapid evolution of football in recent years and how match officials' physical and physiological profile has

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 June 2023 doi:10.20944/preprints202306.0709.v1

changed, it is necessary to have up-to-date benchmarks, possibly on the best-performing population. Thus, the present study aimed to determine the morphological characteristics of an international elite soccer referees' sample, according to the somatotype and the BIVA methods, compare it with other samples in the literature and develop reference tolerance ellipses for the BIVA point graph. We hypothesized that the current sample would show better morphological characteristics than those already described in other studies and, for this reason, should be considered as a reference for investigators and practitioners.

2. Materials and Methods

2.1. Study population and procedures

The study population and procedures of this secondary analysis were described elsewhere [11]. Briefly, the sample consisted of 43 elite international soccer referees (age 38.8 ± 3.6 years) from 6 confederations enrolled during a seminar held in the Federal Technical Center of Coverciano (Italy) in April 2018, during the competitive season. Participants underwent body composition, including somatotype and BIVA. The anthropometrical assessment was described previously [11]. Regarding the BIVA, the impedance measurements were performed using BIA (BIA 101 Anniversary, Akern, Florence, Italy) with an electric current at a frequency of 50 kHz. The device was calibrated in the morning following the manufacturer's instructions. Measurements were made on an isolated cot from electrical conductors. Participants were lying in the supine position with a leg opening of 45° compared to the median line of the body and the upper limbs, distant 30° from the trunk. After cleaning the skin with alcohol, two electrodes (Biatrodes Akern Srl, Florence, Italy) were placed on the right hand back and two electrodes on the neck of the corresponding foot [24]. Bioimpedance vector analysis was carried out using the BIVA method, normalizing resistance (R) and reactance (Xc) parameters for H in meters [24]. Bioelectrical phase angle (PA) was calculated as the arctangent of Xc/R × 180°/π [25]. The study was designed and conducted in accordance with the Helsinki Declaration. The ethics committee of the Italian football association approved this study and all the participants signed written informed consent prior to their inclusion in the study (approval code: 03032018).

2.2. Statistical analysis

The normality of the data was verified by applying the Shapiro–Wilk test, and descriptive statistics were calculated for each independent variable, as reported in table 1. All variables followed the Gaussian distribution. Two participants were excluded from the final sample due to the lack of bioelectrical parameters (n = 41). The somatotype attitudinal distance (SAD) was calculated to compare the current sample with first-division Zimbabwean referees and assistant referees [12] and national and regional-level Brazilian referees [13]. A SAD ≥ 2 was assumed as a distance statistically different between two somatotype means [26]. Each participant was plotted in the tolerance ellipses (50%, 75%, and 95%) of the Italian reference population [24]. A two-sample Hotelling's T2 test was used to determine the BIA vector differences with respect to the reference population [24] and the athletic population [17], as well as to determine differences between somatotypes. Distances between ellipses were calculated by the Mahalanobis test [27]. A p-value < 0.05 was considered significant. BIVA software [27] was used to plot and compare the bioelectrical parameters and compute the tolerance ellipses (50%, 75%, and 95%) of the investigated sample.

Table 1. General, anthropometric, and bioelectrical characteristics of the international-level elite referee.

Variable	Mean	SD	Minimum	Maximum
Age (years)	38.8	3.6	29.5	44.1
Body mass (kg)	75.6	6.7	61.0	94.0
Height (cm)	180.6	6.1	171.0	194.0

Body mass index (km/m2)	23.2	1.4	20.6	25.8
Sum of six skinfolds (mm)	60.3	16.4	34.0	112.6
Endomorphy	2.8	0.9	1.2	5.1
Mesomorphy	6.5	1.2	4.2	8.5
Ectomorphy	2.8	0.7	1.2	4.6
Fat mass (%)	18.4	4.1	11.5	28.0
Resistance (Ω)	498.6	69.0	380.0	622.1
Reactance (Ω)	67.4	8.6	49.9	83.9
Resistance/height (Ω/m)	276.3	39.5	197.9	352.9
Reactance/height (Ω/m)	37.4	5.1	27.0	48.8
Phase angle (°)	7.7	0.7	5.9	9.2

The table describes the Average values, standard deviation (SD), minimum, and maximum values for the general, anthropometric, and bioelectrical characteristics of the international-level elite referee.

3. Results

Table 1 describes the general, anthropometric, and bioelectrical characteristics of the sample. The average and most represented somatotype (n=16) was balanced mesomorph, followed by endomorphic mesomorph (n= 11) and ectomorphic mesomorph (n=11) (fig. 1a and fig. 1b). Mesomorph-endomorph, mesomorph-ectomorph, and central somatotypes comprise only one individual for each category.

The current sample showed a better somatotype than other referees' populations in the literature (fig 1c). Compared to first-division Zimbabwean referees and assistant referees, both samples were, on average, balanced mesomorph, but the values of mesomorphy were higher in the present. The SAD value of 1.9 was slightly lower than the values considered statistically significant (≥ 2), according to Heat & Carter [26]. However, the SAD becomes significant, increasing from 1.9 to 2.1, if only referees are considered in Banda at al. [12] sample (i.e., excluding assistant referees). Compared to the Brazilian national and regional level referees, the current sample was significantly different (SAD = 2.6), with lower endomorphy and both higher ectomorphy and mesomorphy. Similar results were observed by dividing the Brazilian sample into national (SAD = 2.9) and regional (SAD = 2.5) level referees [13]. While the difference was not statistically significant (SAD = 1.8), Chilean referees in the sample had an average somatotype of endomorphic mesomorphs, which contrasts with the dominant balanced mesomorph somatotype of elite international referees [14]. On the other hand, South African officials were very far from the current sample, with a dominant mesomorph-endomorph somatotype and a SAD value of 2.9 [15]. However, the South African referees subsample was even more distant from the international counterpart in the present sample, with a dominant mesomorphic endomorph somatotype (SAD = 3.4).

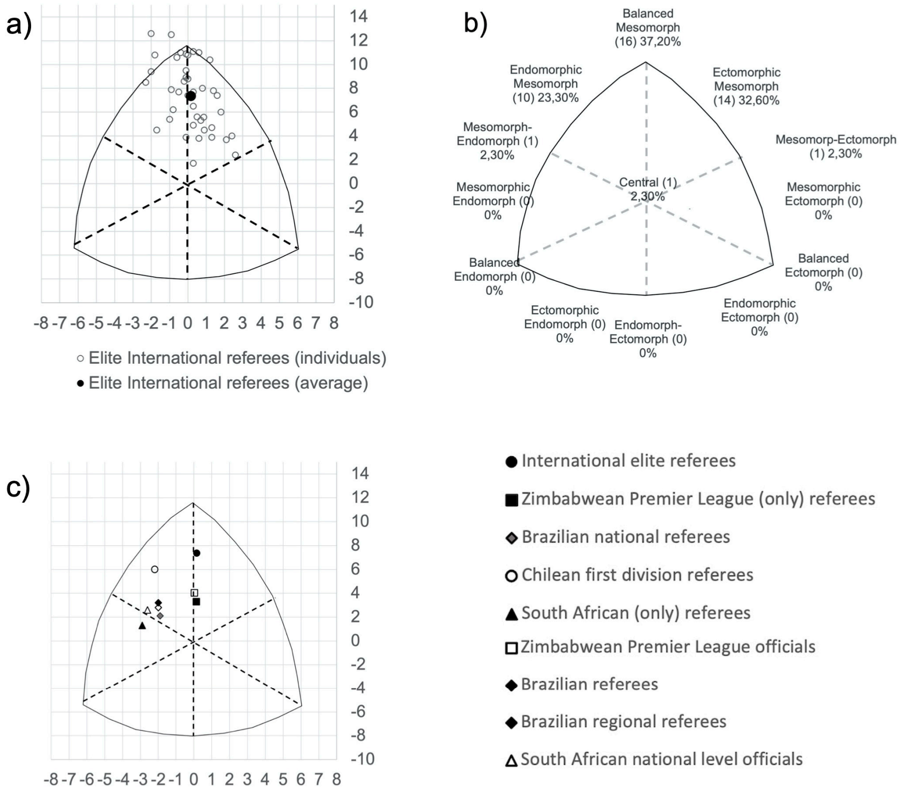

Figure 1. (a) Somatotype distribution of the international elite male soccer referees; **(b)** somatotype categories of the international elite male soccer referees; **(c)** comparison with other published references [12–15].

The BIVA point graph indicates that elite international referees mainly fell in the upper left quadrant (fig. 2a). Figure 2b shows the average position on the BIVA point graph for each somatotype of the current referees' population. Compared with the general male population [24] and athletic reference [17] elite international referees are statistically different. Specifically, they fell more to the left and up than the general population (T2 ≤ 76.6; F = 38.8; D = 1.44; P < 0.001) and to the right and up than the athletic population (T2 ≤ 25.3; F = 12.6; D = 0.8; P < 0.001) (fig 2c) and their specific the 50%, 75%, and 95% tolerance ellipses are represented in figure 2d. Finally, figure 2e compares balanced mesomorph, endomorphic mesomorph, and ectomorphic mesomorph referees. No statistical difference was found.

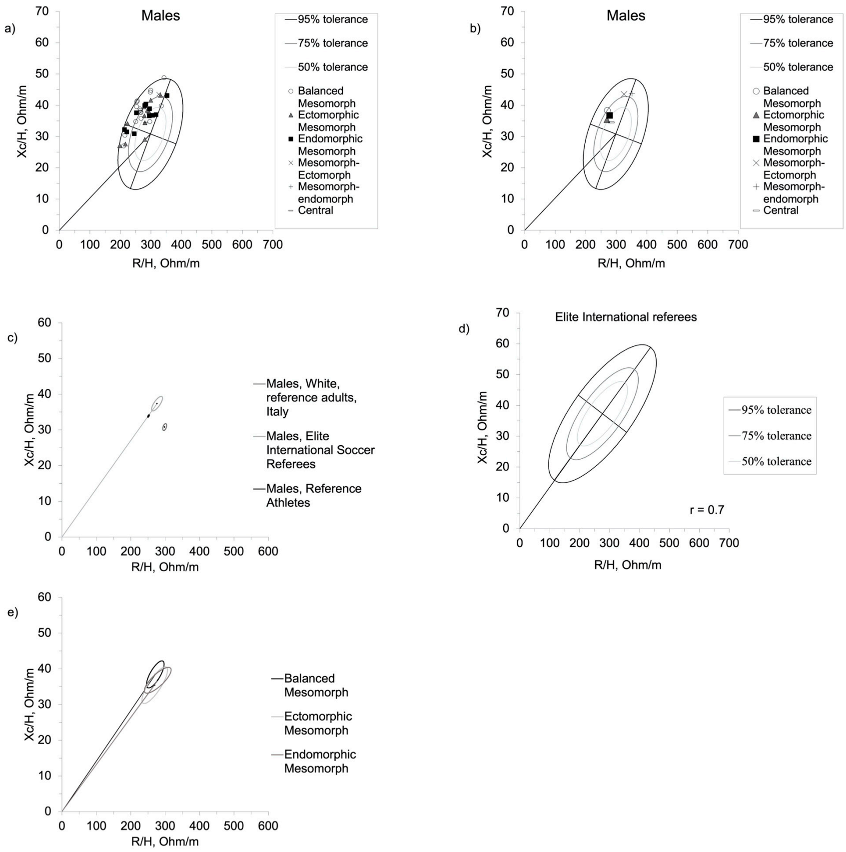

Figure 2. **(a)** Scattergram of the international elite soccer referees, according to the somatotype category, within the BIVA point graph with the 50%, 75%, and 95% tolerance ellipses of the general population; **(b)** the average position of the different somatotypes; **(c)** comparison with the general [24] and athletic references [17]; **(d)** 50%, 75%, and 95% tolerance ellipses derived from the current sample; **(e)** comparison among the different identified somatotypes that characterized elite referees.

4. Discussion

The present study describes a sample of international elite soccer referees. The first important result is that international soccer referees showed a better somatotype than those previously presented in the literature [8–10]. Thus, they can be considered as a reference for practitioners. Secondly, they showed bioelectrical impedance characteristics that are significantly different from the general and the athletic populations [17,24]; specific tolerance ellipses for soccer referees were developed.

In recent years, the intensity of football matches increased, leading to a corresponding increase in soccer refereeing intensity. Consequently, the relative fat mass of soccer referees was lower in more recent samples compared to the previously assessed [8–10]. In the present study, the value of fat mass percentage is higher than that of other studies. Zimbabwean (12.0 ± 2.6%), Greek (16.7 ± 4.5%), and South African (12.6 ± 4.2%) referees showed lower relative fat mass values, while only Brazilian referees (18.5 ± 4.3%) had higher values compared to the present sample [12,13,15,28]. However, this difference can be explained by considering that the studies mentioned above performed the body composition assessment using the anthropometric method. At the same time, the present fat mass percentage value derives from dual-energy X-ray absorptiometry (DXA) [11]. As previously reported, the fat mass values of the current population are underestimated by the commonly used fat mass equations (range 11.0 – 15.2%). Thus, caution should be applied when considering fat mass percentage values in the literature derived from equations developed for the general population. From this point of view, a solution is adopting specific equations for the investigated population [11]. Alternatively, this problem can be avoided using raw skinfold values, like the sum of six or seven skinfolds. Despite the higher value of FM%, the current sample showed the lowest sum of the six skinfolds when compared with other samples in the literature [12,29], confirming that FM% was underestimated in previous studies on soccer referees. Reilly and Gregson [8] indicated a value of FM of 13% in football players using the DEXA technique, and other authors also found values lower than 11% [30,31]. This difference with our referees' sample may be ascribed to the lower level of performance required from referees compared to players. However, we should also consider that elite referees are generally older than other athletes. Indeed, at the elite level, the age range is between 35 and 40 years [3,32,33]. Fernandez Perez et al. [13] indicated as Brazilian regional-level referees had lower fat values than the national ones, probably due to the age difference. Furthermore, a longitudinal study on Brazilian football referees found that their mean body fat percentage increased from 13.2+2.9% to 17.3+3.9 in ten years, moving from a balanced mesomorph pattern to a mesomorph-endomorph pattern [34]. The authors suggest that elite referees are not professionals like elite soccer players, and their training sessions and nutrition are less planned than players.

Previous studies investigated the somatotype of soccer referees. Although the mesomorph component was dominant across the samples in the literature, Brazilian [13] and Chilean [14] referees also showed an important contribution of the endomorph component. On the other hand, Zimbabwean [12] and South African [15] referees showed a balanced mesomorph dominant somatotype, like in the current study. These differences can be explained by considering the above considerations about fat mass, like the role of refereeing intensity and age. Furthermore, also ethnicity can play a role. From this point of view, South American referees seem to have more fat than African ones.

Regarding somatotype, our sample is up to date compared to the previous literature. International elite referees showed a significant distance on the somatochart, characterized by a higher mesomorphy, compared to their Zimbabwean, Brazilian, Chilean, and South African counterparts, which indicates them as the fittest. This difference can be attributed to both the higher competitive level of the current sample and to the evolution of playing intensity experienced by elite referees. Soccer players show a dominant balanced mesomorph morphology, and our result indicates that soccer referees are becoming closer to their players' counterparts [35]. We also found other somatotypes, particularly endomorphic mesomorph and ectomorphic mesomorph, but such variability can be found even in soccer players. By the way, the current sample showed a dominant mesomorph component which is a determinant for high-level performance, regardless of sports discipline.

Regarding the BIVA, elite international referees mainly fell in the upper left quadrant (fig. 2a). Furthermore, some referees fell in the lower left quadrant area to the left of the impedance vector, as previously indicated by Campa for the athletic population [36]. The current sample was characterized by bioelectrical impedance parameters indicating higher cellular mass than the general population but lower than other athletes. This result suggests that soccer referees are a specific population with peculiar bioelectrical properties that differentiate them from the general population, putting them more to the left and up, but also from the athletic population, which shows a shorter vector positioned even more to the left. Thus, although soccer referees are characterized by bioelectrical values associated with better cellular health and body composition than the general population, they are not at the same level as the other athletes. Finally, we did not find differences in the bioelectrical vector between different somatotypes. This result suggests that, despite different morphologies, referees are comparable regarding those parameters that indicate cellular health, hydration, and nutritional status.

The present study has some strengths. Firstly, the sample comprised the best referees at the international level and was assessed on a single occasion. Secondly, fat mass was measured using the gold standard method (i.e., DEXA). Thirdly, the study provides a comprehensive description of an elite sample using multiple methods (i.e., DEXA, Anthropometry, and BIVA), which can serve as a useful reference for researchers and practitioners. Finally, the sample is the most up-to-date among the literature on elite soccer referees, providing insights into the evolution of soccer match intensity. However, the study is limited by its descriptive nature, which only allows for hypothesis generation regarding considerations such as soccer evolution. Additionally, the study did not collect information on the referees' training routines.

5. Conclusions

In summary, our findings suggest that elite soccer referees, based on their body composition, somatotype, and bioelectrical characteristics, are more comparable to soccer players than the general population. As referees are expected to meet high fitness standards, they should be considered athletes, even if they are not professional like their player counterparts. During a game, referees cover an average distance of 10,000-13,000 m [1,2] and expend an estimated 4,700 to 5,600 kJ (1,120-1,340 kcal) [37,38]. Similarly, soccer players cover a similar total distance during matches, but with variations based on tactical position and match demands [39]. Our study implies that elite soccer referees are in good physical condition yet have potential for further improvement through targeted training and nutrition plans.

6. Perspective

The current sample comprised the best international referees and is the most up-to-date in the literature, at least in consideration of the high level. For this reason, both bioelectrical tolerance ellipses and somatotype profiles from the current study can be used by coaches, trainers, and researchers as a reference. Furthermore, the equation of Petri et al. derived from the present sample [11] can be used for fat mass estimation in soccer referees. Overall, the evidence from this study suggests that soccer referees have margins of improvement in body composition and provides the instruments needed for evaluating and monitoring it.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization, P.I. and G.M.; methodology, C.P and S.S.; software, P.I. and S.S.; validation, G.M., G.G.; formal analysis, G.M.; investigation, C.P.; data curation, P.I., C.P., and S.S.; writing—original draft preparation, P.I.; writing—review and editing, C.P., S.S., G.G., and G.M.; visualization, S.S.; supervision, G.M.; project administration, G.G. All authors have read and agreed to the published version of the manuscript." Please turn to the CRediT taxonomy for the term explanation. Authorship must be limited to those who have contributed substantially to the work reported.

Funding: This research received no external funding

Institutional Review Board Statement: The study was designed and conducted in accordance with the Helsinki Declaration. The ethics committee of the Italian football association approved this study (approval code: 03032018).

Informed Consent Statement: All the participants signed written informed consent prior to their inclusion in the study.

Data Availability Statement: the raw data supporting the conclusion of this article will be made available by the authors, based on a reasoned request.

Acknowledgments: The authors gratefully acknowledge FIFA for their support of this research during the experiments.

Conflicts of Interest: The authors did not receive support from any organization for the submitted work. The authors have no competing interests to declare that are relevant to the content of this article.

References

1. Krustrup, P.; Helsen, W.; Randers, M.B.; Christensen, J.F.; MacDonald, C.; Rebelo, A.N.; Bangsbo, J. Activity Profile and Physical Demands of Football Referees and Assistant Referees in International Games. Journal of Sports Sciences 2009, 27, 1167–1176, doi:10.1080/02640410903220310.
2. Weston, M.; Castagna, C.; Impellizzeri, F.M.; Bizzini, M.; Williams, A.M.; Gregson, W. Science and Medicine Applied to Soccer Refereeing: An Update. Sports Med 2012, 42, 615–631, doi:10.2165/11632360-000000000-00000.
3. Helsen, W.; Bultynck, J.-B. Physical and Perceptual-Cognitive Demands of Top-Class Refereeing in Association Football. Journal of Sports Sciences 2004, 22, 179–189, doi:10.1080/02640410310001641502.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 June 2023 doi:10.20944/preprints202306.0709.v1

4. Samuel, R.D.; Englert, C.; Zhang, Q.; Basevitch, I. Hi Ref, Are You in Control? Self-Control, Ego-Depletion, and Performance in Soccer Referees. Psychology of Sport and Exercise 2018, 38, 167–175, doi:10.1016/j.psychsport.2018.06.009.
5. Samuel, R.D.; Tenenbaum, G.; Galily, Y. An Integrated Conceptual Framework of Decision-Making in Soccer Refereeing. International Journal of Sport and Exercise Psychology 2021, 19, 738–760, doi:10.1080/1612197X.2020.1766539.
6. Boullosa, D.A.; Abreu, L.; Tuimil, J.L.; Leicht, A.S. Impact of a Soccer Match on the Cardiac Autonomic Control of Referees. European Journal of Applied Physiology 2012, 112, 2233–2242, doi:10.1007/s00421-011-2202-y.
7. Westerterp, K.R. Exercise, Energy Balance and Body Composition. Eur J Clin Nutr 2018, 72, 1246–1250, doi:10.1038/s41430-018-0180-4.
8. Reilly, T.; Gregson, W. Special Populations: The Referee and Assistant Referee. Journal of Sports Sciences 2006, 24, 795–801, doi:10.1080/02640410500483089.
9. Schenk, K.; Bizzini, M.; Gatterer, H. Exercise Physiology and Nutritional Perspectives of Elite Soccer Refereeing. Scand J Med Sci Sports 2018, 28, 782–793, doi:10.1111/sms.12989.
10. Casajús, J.; Gonzalez-Aguero, A. Body Composition Evolution in Elite Football Referees; an Eleven-Years Retrospective Study. Int J Sports Med 2015, 36, 550–553, doi:10.1055/s-0034-1398582.
11. Petri, C.; Campa, F.; Hugo Teixeira, V.; Izzicupo, P.; Galanti, G.; Pizzi, A.; Badicu, G.; Mascherini, G. Body Fat Assessment in International Elite Soccer Referees. JOURNAL OF FUNCTIONAL MORPHOLOGY AND KINESIOLOGY 2020, 5, doi:10.3390/jfmk5020038.
12. Banda, M.; Grobbelaar, H.W.; Terblanche, E. Body Composition and Somatotypes of Male Zimbabwean Premier League Football Referees. J Sports Med Phys Fitness 2019, 59, doi:10.23736/S0022-4707.18.08326-3.
13. Fernandez Perez, R.; Silva, A.; Paes, M.; Fernandes, L.; Rech, C. Somatotype and Body Composition of Brazilian Football (Soccer) Referees. Archivos de Medicina del Deporte 2011, 28, 238–246.
14. Fernández Vargas, G.E.; Inácio da Silva, A.; Arruda, M. Perfil Antropométrico y Aptitud Física de Árbitros del Fútbol Profesional Chileno. Int. J. Morphol. 2008, 26, doi:10.4067/S0717-95022008000400019.
15. Lategan, L.; Bahdur, K.; Lombard, A. Physiological Profiles of South African Soccer Referees and Assistant Referees. African Journal for Physical Health Education, Recreation and Dance 2011, 17, 489–501.
16. Campa, F.; Gobbo, L.A.; Stagi, S.; Cyrino, L.T.; Toselli, S.; Marini, E.; Coratella, G. Bioelectrical Impedance Analysis versus Reference Methods in the Assessment of Body Composition in Athletes. Eur J Appl Physiol 2022, 122, 561–589, doi:10.1007/s00421-021-04879-y.
17. Campa, F.; Matias, C.; Gatterer, H.; Toselli, S.; Koury, J.C.; Andreoli, A.; Melchiorri, G.; Sardinha, L.B.; Silva, A.M. Classic Bioelectrical Impedance Vector Reference Values for Assessing Body Composition in Male and Female Athletes. IJERPH 2019, 16, 5066, doi:10.3390/ijerph16245066.
18. Micheli, M.L.; Pagani, L.; Marella, M.; Gulisano, M.; Piccoli, A.; Angelini, F.; Burtscher, M.; Gatterer, H. Bioimpedance and Impedance Vector Patterns as Predictors of League Level in Male Soccer Players. International Journal of Sports Physiology and Performance 2014, 9, 532–539, doi:10.1123/ijspp.2013-0119.
19. Carrasco-Marginet, M.; Castizo-Olier, J.; Rodríguez-Zamora, L.; Iglesias, X.; Rodríguez, F.A.; Chaverri, D.; Brotons, D.; Irurtia, A. Bioelectrical Impedance Vector Analysis (BIVA) for Measuring the Hydration Status in Young Elite Synchronized Swimmers. PLoS ONE 2017, 12, e0178819, doi:10.1371/journal.pone.0178819.
20. Giorgi, A.; Vicini, M.; Pollastri, L.; Lombardi, E.; Magni, E.; Andreazzoli, A.; Orsini, M.; Bonifazi, M.; Lukaski, H.; Gatterer, H. Bioimpedance Patterns and Bioelectrical Impedance Vector Analysis (BIVA) of Road Cyclists. J Sports Sci 2018, 36, 2608–2613, doi:10.1080/02640414.2018.1470597.
21. Campa, F.; Mascherini, G.; Polara, G.; Chiodo, D.; Stefani, L. Association of Regional Bioelectrical Phase Angle with Physical Performance: A Pilot Study in Elite Rowers. Muscle Ligaments and Tendons J 2021, 11, 449, doi:10.32098/mltj.03.2021.09.
22. Di Credico, A.; Gaggi, G.; Vamvakis, A.; Serafini, S.; Ghinassi, B.; Di Baldassarre, A.; Izzicupo, P. Bioelectrical Impedance Vector Analysis of Young Elite Team Handball Players. IJERPH 2021, 18, 12972, doi:10.3390/ijerph182412972.
23. Petri, C.; Micheli, M.L.; Izzicupo, P.; Timperanza, N.; Lastrucci, T.; Vanni, D.; Gulisano, M.; Mascherini, G. Bioimpedance Patterns and Bioelectrical Impedance Vector Analysis (BIVA) of Body Builders. Nutrients 2023, 15, 1606, doi:10.3390/nu15071606.
24. Piccoli, A.; Rossi, B.; Pillon, L.; Bucciante, G. A New Method for Monitoring Body Fluid Variation by Bioimpedance Analysis: The RXc Graph. Kidney International 1994, 46, 534–539, doi:10.1038/ki.1994.305.

25. Di Vincenzo, O.; Marra, M.; Scalfi, L. Bioelectrical Impedance Phase Angle in Sport: A Systematic Review. J Int Soc Sports Nutr 2019, 16, 49, doi:10.1186/s12970-019-0319-2.
26. Carter, J.E.L.; Heath, B.H. Somatotyping, Development and Applications; Cambridge studies in biological anthropology; 1. publ.; Cambridge Univ. Pr: Cambridge, 1990; ISBN 978-0-521-35117-1.
27. Piccoli, A.; Pastori, G. BIVA Software. 2002.
28. Rontoyannis, G.P.; Stalikas, A.; Sarros, G.; Vlastaris, A. Medical, Morphological and Functional Aspects of Greek Football Referees. J Sports Med Phys Fitness 1998, 38, 208–214.
29. Casajus, J.A.; Castagna, C. Aerobic Fitness and Field Test Performance in Elite Spanish Soccer Referees of Different Ages. Journal of Science and Medicine in Sport 2007, 10, 382–389, doi:10.1016/j.jsams.2006.08.004.
30. Mascherini, G.; Petri, C.; Galanti, G. Integrated Total Body Composition and Localized Fat-Free Mass Assessment. Sport Sci Health 2015, 11, 217–225, doi:10.1007/s11332-015-0228-y.
31. Mascherini, G.; Castizo-Olier, J.; Irurtia, A.; Petri, C.; Galanti, G. Differences between the Sexes in Athletes' Body Composition and Lower Limb Bioimpedance Values. Muscles Ligaments Tendons J 2017, 7, 573–581, doi:10.11138/mltj/2017.7.4.573.
32. Da Silva, A.I.; Fernandez, R. Dehydration of Football Referees during a Match. Br J Sports Med 2003, 37, 502–506, doi:10.1136/bjsm.37.6.502.
33. Weston, M.; Helsen, W.; MacMahon, C.; Kirkendall, D. The Impact of Specific High-Intensity Training Sessions on Football Referees' Fitness Levels. Am J Sports Med 2004, 32, 54S-61S, doi:10.1177/0363546503261421.
34. Fidelix, Y.L. MORFOLOGIA DO ÁRBITRO DO FUTEBOL APÓS 10 ANOS NA ARBITRAGEM. A. I. 2010, 14.
35. Hazir, T. Physical Characteristics and Somatotype of Soccer Players According to Playing Level and Position. Journal of Human Kinetics 2010, 26, 83–95, doi:10.2478/v10078-010-0052-z.
36. Campa, F.; Silva, A.M.; Talluri, J.; Matias, C.N.; Badicu, G.; Toselli, S. Somatotype and Bioimpedance Vector Analysis: A New Target Zone for Male Athletes. Sustainability 2020, 12, 4365, doi:10.3390/su12114365.
37. Ardigò, L.P.; Padulo, J.; Zuliani, A.; Capelli, C. A Low-Cost Method for Estimating Energy Expenditure during Soccer Refereeing. Journal of Sports Sciences 2015, 33, 1853–1858, doi:10.1080/02640414.2015.1015150.
38. da Silva, A.I.; Fernandes, L.C.; Fernandez, R. Energy Expenditure and Intensity of Physical Activity in Soccer Referees during Match-Play. J Sports Sci Med 2008, 7, 327–334.
39. Clemente, F.M.; Couceiro, M.S.; Lourenço Martins, F.M.; Ivanova, M.O.; Mendes, R. Activity Profiles of Soccer Players During the 2010 World Cup. Journal of Human Kinetics 2013, 38, 201–211, doi:10.2478/hukin-2013-0060.