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Body Composition and Physical Performance: Kinanthropometry Assessment of Elite Male Rugby Referees

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Abstract

Introduction: Elite rugby referees are required to maintain high levels of physical fitness to cope with the intermittent high-intensity demands of the game. However, limited data are available on their kinanthropometric characteristics. This study aimed to describe the body composition profiles of elite male rugby referees and examine their association with physical performance. **Methods:** Nineteen elite male Italian rugby referees (age: 31.2 ± 4.6 years; BMI: 23.4 ± 2.1 kg·m^{-2}) underwent standardized ISAK anthropometric assessments to determine body composition variables, including somatotype, estimates of body mass components, and several anthropometric indices. Physical performance was evaluated through strength (handgrip and mid-thigh pull test) and endurance (Bronco test) assessments. Descriptive statistics were calculated, and Pearson's correlation coefficients (r) were used to explore associations between body composition and performance. **Results:** Somatotype analysis revealed a predominance of endomorphic-mesomorph and mesomorphic-endomorph profiles, with fewer balanced mesomorph and ectomorphic-mesomorph individuals. Significant correlations were observed between body composition and performance. Age, sum of skinfolds, mesomorphy, and endomorphy were positively associated ($p < 0.05$) with mean time in the Bronco test, whereas ectomorphy showed a significant inverse relationship ($r = -0.75$, $p < 0.05$). Scatterplots with regression lines illustrated these associations. **Conclusion:** Elite rugby referees primarily displayed mixed somatotypes with high mesomorphic and endomorphic components. Body composition characteristics, particularly ectomorphy and fatness, were associated with endurance performance. This study provides, for the first time, a full anthropometric profile of elite rugby referees, highlighting the relevance of regular kinanthropometric monitoring to optimize their physical preparation.

Keywords: Anthropometry, Body composition, Endurance, ISAK, Strength

Resumen

Introducción: Los árbitros de rugby de élite deben mantener un alto nivel de condición física para afrontar las exigencias intermitentes de alta intensidad del juego. Sin embargo, existe poca información disponible sobre sus características cineantropométricas. Este estudio tuvo como objetivo describir los perfiles de composición corporal de árbitros de rugby masculinos de élite y examinar su asociación con el rendimiento físico. **Métodos:** Diecinueve árbitros de rugby italianos de élite (edad: 31,2 ± 4,6 años; IMC: 23,4 ± 2,1 kg•m^{-2}) se sometieron a evaluaciones antropométricas estandarizadas según el protocolo ISAK para determinar variables de composición corporal, incluyendo el somatotipo, estimaciones de los componentes de la masa corporal y varios índices antropométricos. El rendimiento físico se evaluó mediante pruebas de fuerza (fuerza de prensión manual y prueba de tracción a media altura del muslo) y resistencia (prueba Bronco). Se calcularon estadísticas descriptivas y se utilizaron coeficientes de correlación de Pearson (r) para explorar las asociaciones entre la composición corporal y el rendimiento. **Resultados:** El análisis del somatotipo reveló un predominio de perfiles endomórfico-mesomórficos y mesomórfico-endomórficos, con menor presencia de individuos mesomorfos equilibrados y ectomórfico-

mesomórficos. Se observaron correlaciones significativas entre la composición corporal y el rendimiento. La edad, la suma de los pliegues cutáneos, la mesomorfia y la endomorfia se asociaron positivamente ($p < 0.05$) con el tiempo promedio en la prueba Bronco, mientras que la ectomorfia mostró una relación inversa significativa ($r = -0,75$, $p < 0.05$). Los diagramas de dispersión con líneas de regresión ilustraron estas asociaciones. **Conclusión:** Los árbitros de rugby de élite mostraron principalmente somatotipos mixtos con altos componentes mesomórficos y endomórficos. Las características de la composición corporal, en particular la ectomorfia y el porcentaje de grasa corporal, se asociaron con el rendimiento de resistencia. Este estudio proporciona, por primera vez, un perfil antropométrico completo de árbitros de rugby de élite, destacando la relevancia del seguimiento cineantropométrico regular para optimizar su preparación física.

Palabras Clave: Antropometría, Composición corporal, Resistencia, ISAK, Fuerza.

Introduction

Elite rugby referees are required to sustain high-intensity intermittent efforts, maintain continuous movement, and make rapid decisions throughout the match, often covering more than 7 km per game with frequent accelerations and directional changes (Sant'anna *et al.*, 2021). These demands require a balanced combination of strength, power, and aerobic endurance.

While extensive research has focused on rugby players' body composition and its relationship to performance, considerably less is known about rugby referees (Toselli *et a*l., 2019; Nescolarde *et al.*, 2023; Holway *et al*., 2024). Preliminary studies suggest that referees present lower muscle mass and aerobic fitness than players but must maintain optimal physical conditioning to ensure match control and decision accuracy. Understanding their kinanthropometric profile is therefore crucial for developing targeted preparation strategies.

Body composition is a key determinant of physical performance and can influence sport performance (Campa *et al.*, 2019; Martínez-Mireles *et al.*, 2025). Its assessment can be effectively performed through anthropometric methods, which allow estimation of the main body mass components (fat mass, skeletal muscle mass, and bone mass) and the calculation of derived indices. In this context, somatotype analysis (endomorphy, mesomorphy, ectomorphy) according to the Heath-Carter method (Carter JEL, 2002) provides an integrative description of overall physique, combining information on adiposity, muscularity, and linearity. The combination of somatotype and body composition estimates offers a comprehensive framework to characterize physical profiles and to investigate their potential impact on performance.

This study aimed to describe for the first time the full anthropometric and somatotype profile of elite male rugby referees and explore the relationships between body composition characteristics and strength and endurance performance outcomes.

Materials and Methods

All research procedures were reviewed and approved by the Ethical Committee board of the University of Padova and are conform to the Declaration of Helsinki concerning studies involving human subjects. After being provided with a detailed written explanation of the procedures, the participants gave their written informed consent.

Participants

Nineteen elite male rugby referees (age: 31.2 ± 4.6 years; BMI: 23.4 ± 2.1 $kg \cdot m^{-2}$) volunteered to participate in the study. All assessments were conducted at the national rugby training center under standardized conditions. Participants were instructed to refrain from strenuous exercise and to maintain their usual diet in the 24 hours preceding the assessments.

Procedures

The anthropometric assessments were conducted by operators certified by the International Society for the Advancement of Kinanthropometry, following international standards (International Society for Advancement of Kinanthropometry., 2001). Body mass and stature were measured using a scale with an integrated stadiometer (Seca, Hamburg, Germany), with a sensitivity of 0.1 kg and 0.1 cm, respectively. Body mass index was calculated as body mass (kg) divided by squared stature (m^2). Skinfold thicknesses were measured using a generic type A caliper (Holway, California, USA). Girths were measured using a similar measuring tape (Lufkin, Apex Tool Group, USA) with a sensitivity of ±0.1 mm. Breadths and lengths were measured to the nearest 0.1 cm using a sliding

caliper (Holway, California, USA). Somatotype components were calculated according to the Heath and Carter method (Carter JEL, 2002). Fat mass was estimated using the predictive equation proposed by Kanellakis *et al*. (Kanellakis *et al.*, 2017), while skeletal muscle and bone mass was estimated according to the equation developed by Kerr et al. (Baglietto et al., 2024).

Performance test

Handgrip strength was measured using a calibrated handheld dynamometer (Ingrip, InBody, Italy), with participants performing three maximal voluntary contractions with their dominant and not dominant hand; the highest value was recorded. Maximal isometric strength of the lower limbs was assessed via the mid-thigh pull test, performed on two force platforms (K-Deltas, Kinvent, France). Participants exerted maximal effort for 3–5 seconds from a standardized mid-thigh position, and peak force as well as rate of force development were recorded. Endurance performance was assessed using the Bronco test, which consists of running shuttles of 20, 40, and 60 meters, repeated five times consecutively (for a total of 1200 m). Participants were instructed to complete the distance in the shortest possible time, and the total time was used as the performance outcome.

Statistical analysis

All analyses and visualizations (correlation heatmaps, scatterplots with regression lines, and somatocharts) were performed using Python (pandas, matplotlib, seaborn libraries). Descriptive statistics were computed for all anthropometric, body composition, and performance variables, and are presented as mean ± standard deviation (SD), minimum, and maximum values. Pearson's correlation coefficients (r) were used to explore the relationships between body composition variables and performance measures. Correlation strength was interpreted as: trivial (<0.1), small (0.1–0.3), moderate (0.3–0.5), large (0.5–0.7), very large (0.7–0.9), and nearly perfect (>0.9). Statistical significance was set at $p < 0.05$.

Results

Descriptive statistics for all anthropometric, body composition, and performance variables are reported in Table 1.

Table 1. Anthropometric and performance variables of the participants

Variable	Mean	± Std. dev.	Min	Max
Basics measurements				
Age (years)	37	8.83	25	51
Body Mass (kg)	81.02	11.61	65.4	106.9
Stretch stature (cm)	175.42	6.99	163.0	188.3
Sitting height (cm)	92.26	3.52	87.0	99.0
Arm span (cm)	178.18	8.01	166.6	192.4
Skinfolds (mm)				
Triceps	10.89	3.9	6.0	19.0
Subscapular	13.18	4.48	8.0	24.0
Biceps	5.47	3.0	2.0	13.0
Iliac crest	15.08	5.63	8.0	27.0
Supraspinale	11.58	4.57	5.0	22.0
Abdominal	18.29	7.27	9.0	35.0
Thigh	15.76	6.13	9.0	29.0
Calf	9.03	3.73	4.0	19.0
Sum 8 skinfolds	99.29	31.62	55.0	176.0
Girths (cm)				
Head	57.72	1.62	55.0	60.4
Neck	38.01	1.76	35.5	41.2
Arm relaxed	33.28	2.56	27.5	39.5
Arm flexed and tensed	35.21	2.97	29.5	42.4
Forearm	28.39	1.98	25.9	33.8
Wrist	16.87	0.75	15.7	18.3
Chest	105.03	6.46	93.5	116.8
Waist	87.21	7.46	78.7	100.6

Hips	99.92	6.36	90.5	112.3
Thigh 1cm gluteal	60.47	4.76	52.0	69.1
Thigh middle	54.61	6.82	36.0	64.1
Calf	38.9	2.88	34.0	46.0
Ankle	23.5	1.45	20.9	26.2
Lengths and heights (cm)				
Acromiale-radiale	33.27	2.01	29.7	37.6
Radiale-Stylion	27.1	1.43	24.1	29.0
Midstylion-Dactylion	19.53	0.98	18.1	21.2
Iliospinale height	102.45	6.19	93.4	115.0
Trochanterion height	95.26	5.7	86.4	109.0
Trochanterion-tibiale laterale	43.59	2.28	39.6	47.0
Tibiale laterale height	48.68	3.45	42.7	54.1
Foot	26.96	1.25	24.7	29.1
Tibiale mediale-sphyrion tibiale	40.22	2.66	36.3	44.2
Breadths (cm)				
Biacromial	41.37	2.01	38.6	44.7
Antero-posterior abdominal depth	21.65	2.26	18.0	26.5
Biiliocristal	30.35	2.59	25.3	36.2
Transvers chest	31.89	2.5	27.1	35.5
Antero-posterior chest depth	19.81	1.98	17.2	24.7
Humerus	7.07	0.55	6.1	8.8
Bi-styloid	5.62	0.2	5.3	6.0
Femur	9.67	0.53	8.8	10.5
Bimalleolar	7.32	0.48	6.4	8.6
Somatotype				
Endomorphy	3.82	1.19	2.38	6.3
Mesomorphy	5.93	1.26	4.16	9.09
Ectomorphy	1.38	0.79	0.1	2.73
Body mass components				
Muscle mass by Kerr (kg)	37.65	6.64	28.92	54.63
Bone mass by Kerr (kg)	9.35	1.52	6.05	11.74
Fat mass by Kanellakis (%)	20.84	4.23	16.06	27.25
Fat mass by Kanellakis (kg)	17.22	5.62	10.94	28.05
Anthropometric indices				
Body mass index (kg/m2)	26.27	2.88	22.37	31.69
Muscle bone index	4.07	0.62	3.29	5.62
Relative arm span (%)	1.02	0.02	0.98	1.04
Cormic index (%)	52.61	1.23	50.88	54.96
Acromio-iliac index (%)	73.34	4.76	65.54	82.84
Crural index (%)	92.39	6.59	83.07	109.52
Thoracic index	62.48	8.09	49.00	84.87
Performance tests				
Bronco test - mean time (s)	4.91	0.39	4.44	5.5
Dominant handgrip strength (kg)	50.78	9.49	39.2	70.1
Non-dominant handgrip strength (kg)	51.06	11.14	33.6	79.5
MTPT test Fmax tot (N)	1677.33	288.07	1242.2	2178.1
MTPT RFD tot (N/s)	7010.27	3204.41	1838.0	11629.0
MTPT Fmax D (N)	816.71	156.99	563.4	1080.0
MTPT RFD D (N/s)	3575.67	1604.42	1165.0	6645.0
MTPT Fmax ND (N)	860.69	161.67	658.2	1184.6
MTPT RFD ND (N/s)	3621.27	1655.69	1392.0	6338.0

Abbreviations: MTPT = Mid-Thigh Pull Test; Fmax = Maximum Force; RFD = Rate of Force Development; D = Dominant Limb; ND = Non-Dominant Limb; tot = Total (combined value of both limbs).

Somatotype analysis revealed distinct body composition profiles among participants, with a predominance of endomorphic-mesomorph and mesomorphic-endomorph types, and fewer balanced mesomorph and ectomorphic-mesomorph individuals. Each athlete was plotted on a Heath-Carter somatochart according to their endomorphy, mesomorphy, and ectomorphy values (Figure 1). Points are color-coded by somatotype category, with the individual somatotype triplets (Endo–Meso–Ecto) displayed next to each point.

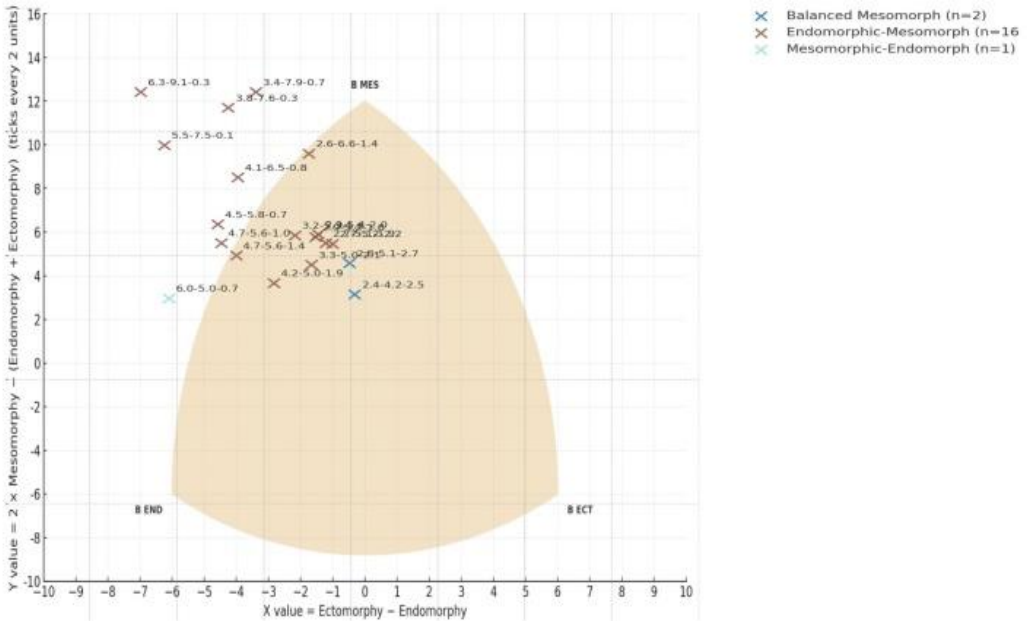

Figure 1. Somatochart showing the distribution of participants according to their Heath-Carter somatotype. Points are color-coded by category, with the corresponding Endomorphy–Mesomorphy–Ectomorphy triplets shown next to each point.

Correlation analyses revealed several significant associations between body composition and performance (Figure 2). Higher age, sum of skinfolds, mesomorphy, and endomorphy were positively associated with mean time in the Bronco test ($p < 0.05$). Conversely, ectomorphy showed a significant inverse relationship with the mean time in the Bronco test ($r = −0.75$, $p < 0.05$).

To further illustrate these relationships, scatterplots with regression lines were generated for each significant correlation (Figure 3).

Discussion

This study provides the first complete kinanthropometric profile of elite male rugby referees, combining somatotype, estimates of body mass components, anthropometric indices, and performance testing. Most referees were classified as endomorphic-mesomorph or mesomorphic-endomorph, indicating a predominance of muscular development combined with moderate fatness, while few showed balanced mesomorph or ectomorphic-mesomorph profiles. These findings are consistent with the physical demands of rugby refereeing (Suarez-Arrones *et al.,* 2013; Le Roux *et al.*, 2021), which require sufficient muscularity to sustain repeated accelerations and positional stability, while carrying some non-functional mass that may reflect lower training volumes than players.

Alongside somatotype, several anthropometric indices were considered to provide a more functional interpretation of the data. The crural index, derived as length tibiale mediale-sphyrion tibiale / length trochanterion-tibiale laterale *100, and the thoracic index, derived as antero-posterior chest depth / transverse chest breadth * 100. offer further insight into body proportions (Holway and Garavaglia, 2009). Participants generally showed intermediate crural index values, indicating balanced lower-limb proportions suited for repeated accelerations and decelerations, and thoracic index values consistent with well-developed thoracic morphology. Although these indices were not directly correlated with performance outcomes, they contribute to defining the morphological profile of referees and could serve as useful reference markers in longitudinal monitoring. The ape index (arm span / stretched stature * 100) further complemented the analysis, showing values close to 1.0 on average, indicating proportional or slightly longer upper limbs. While not directly correlated with performance outcomes in this sample, a positive ape index (arm span greater than height) is often associated with mechanical advantages in upper-body force application and reach (Ginszt *et al.*, 2023).

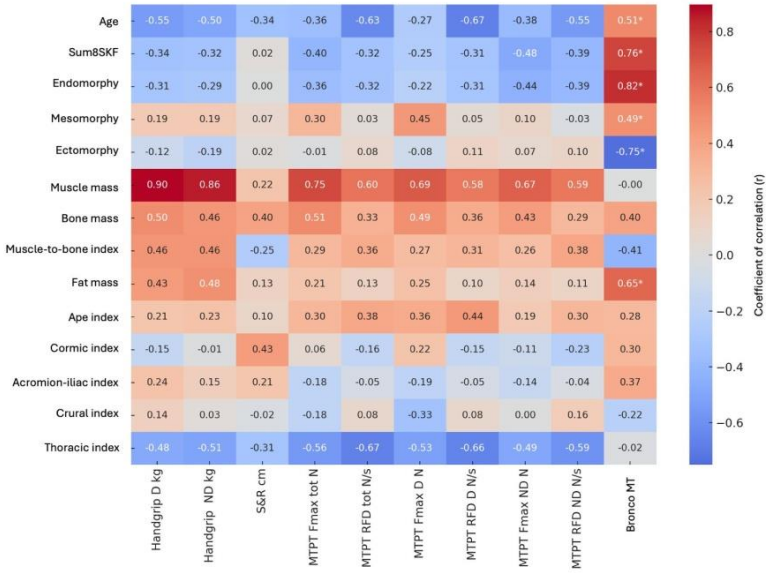

Figure 2. Heat map of Pearson's correlations between body composition and performance variables. Asterisks indicate statistically significant correlations ($p < 0.05$).

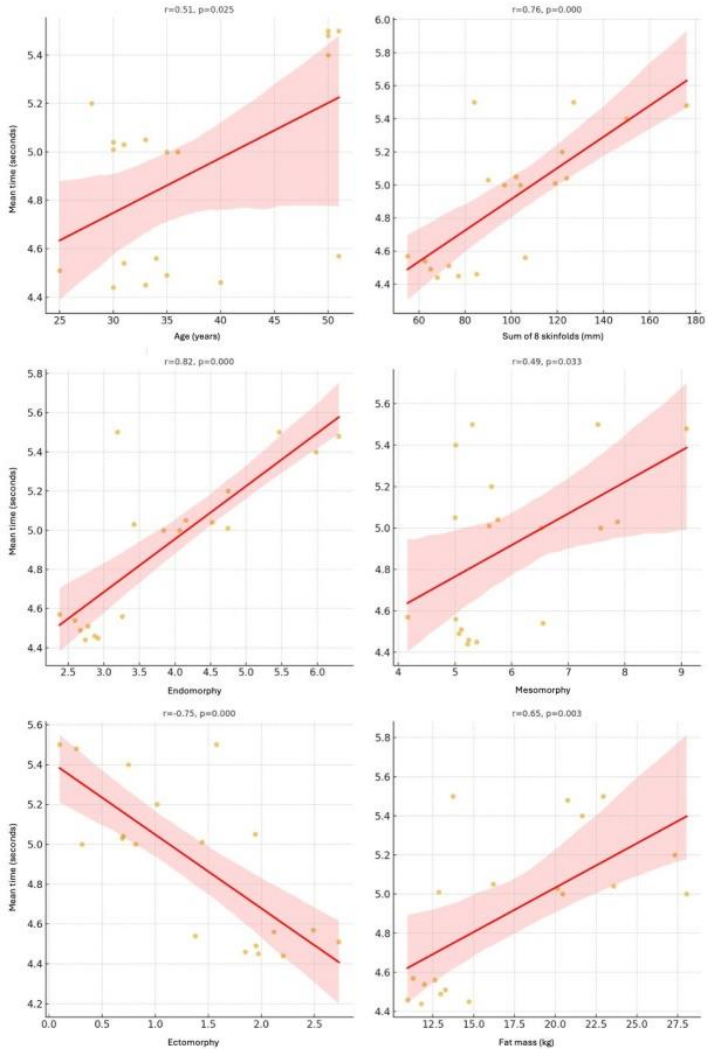

Figure 3. Scatterplots showing significant correlations between body composition and performance variables. Each plot includes the regression line and 95% confidence band.

The association analysis revealed that higher endomorphy, mesomorphy, sum of skinfolds, and age correlated with slower Bronco test times. The sum of the eight skinfolds in this sample aligned closely with the 50th

percentile for age- and sex-specific reference values from the general population (Campa *et al*., 2025). This indicates that, on average, the referees showed a level of subcutaneous fat comparable to normative standards. However, it should be noted that such reference values are derived from non-athletic populations and may not represent the optimal range for individuals involved in high-performance or elite sport contexts (Santos, 2014). Considering the physical demands of rugby officiating, a lower relative fat mass could be advantageous to improve movement efficiency, aerobic capacity, and fatigue resistance during match play. Higher ectomorphy correlated inversely with Bronco time ($r \approx -0.75$). This suggests that greater linearity and lower fatness benefit endurance performance, whereas excess fat or higher overall body mass may hinder movement efficiency. These findings mirror those in rugby players, where increased adiposity impairs aerobic and sprint performance, while leaner morphotypes achieve better endurance outcomes. Although strength tests (handgrip and mid-thigh pull) were not strongly correlated with body composition, they remain critical for the demands of refereeing (e.g. resisting contact, rapid repositioning). The results suggest that maintaining adequate muscularity is beneficial, but only insofar as it does not substantially increase fatness and impair endurance.

This study is the first to deliver a comprehensive anthropometric profile of elite rugby referees, offering normative data to guide conditioning programs, selection standards, and long-term monitoring. Future research should expand to larger and multi-national samples, track longitudinal changes across the season, and investigate the effects of body composition on decision-making and movement efficiency during match play. Some limitations should be acknowledged. First, the relatively small sample size may not be sufficient to fully capture the influence of body composition on physical performance, and it limits the statistical power for detecting more subtle associations. Second, the body composition estimation equations used in this study, although validated in general or athletic populations, were not specifically developed for elite rugby referees, and may therefore introduce a degree of estimation bias in this unique cohort. Finally, the present findings cannot be generalized to referees from other sports or to female referees, as sport-specific physical demands and sex-related differences in body composition may lead to distinct anthropometric and performance profiles.

Conclusions

This study provides the first comprehensive kinanthropometric profile of elite male rugby referees, combining somatotype, estimates of body mass components, anthropometric indices, and physical performance assessments. The referees predominantly exhibited endomorphic-mesomorph and mesomorphic-endomorph somatotypes, characterized by moderate adiposity and muscular development. Higher levels of endomorphy, mesomorphy, skinfold thickness, and older age were associated with poorer endurance performance, while higher ectomorphy correlated with better endurance capacity. These findings suggest that excessive fatness and overall mass may impair movement efficiency, whereas greater linearity may be advantageous for endurance-related tasks. These results highlight the importance of regular kinanthropometric monitoring to guide the physical preparation of rugby referees. Establishing normative data on their anthropometric characteristics can support targeted conditioning strategies and contribute to optimizing performance and long-term officiating standards.

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Conflicts of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Informed Consent Statement

All the athletes included in the study provided written informed consent.