

Body composition distinguishes between low- and expert-level professional futsal referees in CONCACAF

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Published online: April 30, 2026

Accepted for publication: April 15, 2026

DOI:10.7752/jpes.2026.04077

Abstract:

Anthropometry provides valuable information about physical characteristics that may influence performance in futsal. This study aims to compare body composition, circumferences, skinfold measurements, and results from physical fitness tests between professional futsal referees with low experience level (LEPFR) and high experience level (HEPFR). Twenty-two futsal referees (LEPFR and HEPFR) participated in a cross-sectional evaluation that included body composition measurements and assessments of physical fitness through three main performance tests: the 20-meter sprint test, the change of direction ability (CODA) test, and the ARIET test. T-test analyses indicated significant differences in body weight ($p = 0.05$), fat mass ($p = 0.05$), subscapular skinfolds ($p = 0.001$), tricipital skinfolds ($p = 0.001$), and abdominal skinfolds ($p = 0.05$) between the groups, with high-experience referees showing better values in these measures. Correlation analyses revealed a small positive correlation between the 20-meter sprint and thigh circumference ($r = 0.41$), a moderate inverse correlation between biceps circumference and the CODA test ($r = -0.43$), and a strong positive correlation between the CODA test and thigh circumference ($r = 0.57$). This study highlights the importance of specific anthropometric measurements, especially thigh circumference, in the assessment of the physical condition of futsal referees. These findings support the inclusion of anthropometric assessments in physical fitness evaluations to optimize training strategies. Future research should further explore these relationships, focusing on their implications for sports training and the development of personalized programs for futsal referees and athletes.

Key Words: Referees, anthropometrics profile; physical fitness; Futsal, Performance;

Introduction

Futsal, a variant of soccer played on a smaller indoor field, has experienced a surge in global popularity, leading to an increased demand for higher officiating standards to preserve the integrity and flow of the game (Spyrou et al., 2020). Professional futsal referees are essential in ensuring fair play, enforcing regulations, and managing the dynamics of matches (Castillo-Rodríguez et al., 2023). As the pace and intensity of futsal continue to rise, the physical demands on referees have intensified, highlighting the need to examine their anthropometric profiles and fitness parameters to enhance their performance (Martinez-Torremocha et al., 2023). Gaining knowledge into these factors can guide the development of targeted training programs and selection criteria, ultimately improving referees' effectiveness on the field (Serrano et al., 2021).

Anthropometry, the scientific study of human body measurements and proportions, offers valuable information into the physical characteristics that can influence performance in futsal (Gomez-Campos et al., 2023; Sekulic et al., 2021; Stubbs-Gutierrez & Medina-Porqueres, 2021). In fact, the anthropometric profile of a referee significantly impacts their agility, speed, and overall physical capabilities, which are essential for effectively navigating the playing area while maintaining a clear view of the action (Ferraz et al., 2020). Research has indicated that specific body compositions and somatotypes correlate with athletic performance, suggesting that referees possessing certain physical attributes may be better equipped to meet the demands of the game (Castillo-Rodríguez et al., 2021). In this sense, mesomorphic individuals, known for their muscularity and

strength, may excel in sports that require explosive movements and agility (González-Ortega et al., 2023). Therefore, understanding the distribution of somatotypes among futsal referees can provide critical insights into the physical attributes that enhance officiating effectiveness, ultimately contributing to improved game management and performance (Díaz Muñoz, 2016; Rivera & Naranjo, 2016). In addition to anthropometric profiles, physical fitness parameters are critical for assessing the capabilities of futsal referees. Key fitness components include speed, agility, endurance, and anaerobic power (Spyrou et al., 2020; González-Ortega et al., 2023). These components are essential for referees, who must make quick decisions, change direction rapidly, and maintain high levels of activity throughout the match. Speed is a fundamental attribute for referees, as it allows them to position themselves optimally during play.

On the one hand, referees performed during their annual training test the 20-meter sprint test is a widely used measure of linear speed and has been employed in various studies to assess athletic performance (Slawinski et al., 2017; Loturco et al., 2019, 2020). This test involves sprinting a distance of 20 meters from a standing start, with the time recorded to evaluate speed. Research has indicated that faster referees can better keep up with the pace of the game, thereby enhancing their ability to make accurate decisions (Serrano et al., 2021). On the other hand, the ability to change direction quickly while maintaining control, is another critical fitness parameter for referees. In this sense, the Change of Direction Ability (CODA) test evaluates a referee's capacity to maneuver effectively in response to the dynamic nature of the game. Studies have shown that agility is a significant predictor of performance in sports that require rapid directional changes (González-Ortega et al., 2023; Martinho et al., 2023). For futsal referees, possessing high agility levels is essential for navigating the court and maintaining an optimal position to observe play (Yuosif et al., 2022). Finally, referees are evaluated on anaerobic power, the ability to exert high-intensity effort in short bursts, is vital for referees who must sprint, change direction, and react quickly during matches (Dixon, 2014; Serrano et al., 2021). In this respect, the ARIET test is designed to assess anaerobic capacity and overall fitness levels, providing a comprehensive evaluation of a referee's physical capabilities (González-Ortega et al., 2023). This test typically involves a series of high-intensity sprints and movements that simulate the demands of a futsal match, allowing for a realistic assessment of a referee's performance potential (Castagna et al., 2012).

The relationship between age and experience in soccer referees is complex and multifaceted. As referees age, they often accumulate valuable experience that enhances their decision-making skills and game management abilities. Older referees may possess a deeper understanding of the game's nuances, allowing them to anticipate player behavior and make more informed calls (López-Aguilar et al., 2020). However, physical attributes such as speed and agility may decline with age, potentially impacting their on-field performance (Diotaiuti et al., 2017). Conversely, younger referees may exhibit superior physical fitness, enabling them to keep pace with the game more effectively (Micoogullari et al., 2017). Balancing these factors is crucial; thus, ongoing training and psychological support can help referees maintain their performance levels, regardless of age. Ultimately, fostering a culture of continuous development can empower referees to leverage their experience while adapting to the physical demands of the sport.

Moreover, the integration of age-specific training programs can enhance the physical capabilities of older referees, allowing them to remain competitive. Research indicates that tailored fitness regimens can mitigate age-related declines in performance (González-Oya & Dosil, 2004). Additionally, mentorship programs pairing younger referees with seasoned officials can facilitate knowledge transfer, enriching the overall quality of officiating (Myers et al., 2012). This collaborative approach not only enhances the skill set of younger referees but also reinforces the confidence of older referees, creating a more cohesive officiating community. By recognizing the unique contributions of referees at different stages of their careers, soccer organizations can cultivate an environment that values both experience and physical capability.

Given the physical demands placed on futsal referees, tailored training and conditioning programs are essential for optimizing performance (Serrano et al., 2021). Research has demonstrated that specific training regimens focusing on speed, agility, and anaerobic power can significantly enhance athletic performance (González-Ortega et al., 2023; Serrano et al., 2021). For referees, incorporating drills that mimic match conditions can improve their ability to respond effectively during games. Moreover, understanding the anthropometric profiles of referees can inform training strategies that target specific physical attributes. For instance, referees with a predominance of ectomorphic characteristics may benefit from strength training to enhance their muscularity and power, while mesomorphic referees may focus on maintaining their agility and speed (González-Ortega et al., 2023). In sum, the anthropometric profiles and physical fitness parameters of professional futsal referees are critical factors influencing their performance on the field (Martinez-Torremocha et al., 2023). Considering the gap in research on futsal referees and the potential to provide knowledge into the relationship between physical attributes and training development, this study aims to investigate differences in body composition and physical fitness between Low Experience Futsal Referees (LEPFR) and High Experience Futsal Referees (HEPFR). By analyzing these physical characteristics, the research seeks to shed light on the specific physical demands associated with officiating in futsal. Understanding how these traits differ between the two groups will help identify the key physical requirements for effective refereeing.

Furthermore, the study will employ correlation analysis to explore the relationships between anthropometric measures and physical fitness outcomes. This analysis will aim to uncover how body composition and physical fitness impact refereeing performance. The knowledge gained will inform training and selection processes, ultimately contributing to the development of more effective referees in futsal. By identifying the key physical characteristics that distinguish different levels of expertise, this study seeks to enhance the overall quality of officiating and support the professional development of referees within the CONCACAF Excellence Program.

Material & Methods

Design

This study follows a cross-sectional design conducted during the 2024/2025 season in Cuba. The assessments took place at the start of the season and were part of the regular physical evaluations within the CONCACAF Excellence Program.

Participants

A convenience sampling strategy was used to recruit participants through direct contact with CONCACAF. A total of 22 futsal referees affiliated with the CONCACAF Excellence Program from Cuba, categorized into two distinct groups based on their expertise levels: LEPFR and HEPFR. The LEPFR group (age: 23.45 ± 3.30 ; years of experience: 5.45 ± 3.14 years) comprised referees who had recently entered the professional arena, possessing limited experience in officiating high stakes matches. These referees typically had less than five years of experience at the professional level and were still developing their skills in decision-making, game management, and understanding of the rules. In contrast, the HEPFR group (age: 34.73 ± 4.56 ; years of experience: 16.73 ± 4.35 years) consisted of seasoned referees with extensive experience in the professional futsal domain. These individuals had officiated numerous high-level matches, including national and international competitions, and had a minimum of five years of experience. Their advanced skills in interpreting the game, managing player interactions, and making quick, accurate decisions under pressure distinguished them from their less experienced counterparts.

Regarding the sample size, a minimum of twenty-one participants was necessary to achieve a statistical power of 83.5% (actual power). This determination was made using an a priori power analysis for a t-test, focusing on correlation analysis with an alpha level set at 0.05, a desired power ($1 - \beta$ error probability) of 0.80, and a medium-to-large effect size derived from previous research. The calculations for sample power were conducted using G*Power software (University of Düsseldorf, Düsseldorf, Germany). All the information about the SRs' characteristics and training background is shown in Table 1.

All participants were instructed to wear comfortable sports clothes and soccer shoes, as this was vital for the appropriate administration of the test battery and warm-up experimental sessions (Figure 1, 2 and 3). Each SR signed a written informed consent form before participation and completed a detailed questionnaire recording training type and duration. In addition, a self-made questionnaire about the routines of the SR from when they come to the stadium until they start the match was recorded. The eligibility criteria for being included in the final sample were (i) to be older than 18 years, (ii) to be actively federated and members of CONCACAF Excellence Program, (iii) not presenting any injuries during the last 2 months, (iv) giving consent, and (v) participating in all sessions during the study periods. The present study received approval from the ethics committee certified by the National Council of Health. It was conducted in accordance with the principles outlined in the Declaration of Helsinki.

These referees trained five times a week (90 min per session) and referee one match. The training sessions were focused on rule interpretation and application (60% of training time), physical conditioning and fitness (30% of training time), and communication and decision-making skills (10% of training time). The weekly training program for semi-professional referees is structured to address the multifaceted physical demands of their role. Each component of the program is strategically designed to improve specific attributes essential for optimal performance during matches: i) Endurance

Training: the inclusion of aerobic exercises helps referees maintain stamina throughout the game, allowing them to cover significant distances while making quick decisions; ii) Strength Training: full body exercises such as the Bench Press, Pull-Ups, Back Squat, and Hip Thrust are crucial for building overall body strength, which supports the physical demands of officiating; iii) Plyometric Exercises: movements like the Counter Movement Jump (CMJ) and Hurdle Jumps enhance explosive power and agility, enabling referees to react swiftly to dynamic game situations, and Lower Body Focus: Exercises such as Squat Jumps, Hamstring Slides, and Glute Bridges target the lower body, improving strength and stability, which are vital for quick lateral movements and maintaining balance during high-intensity activities.

This comprehensive training approach not only prepares referees physically but also contributes to their overall performance and effectiveness on the field. Regular assessment and adaptation of the training program can further optimize their readiness for competitive matches. Generally, training sessions comprised a warm-up, main part, and cooldown.

Procedure

Researchers visited the concentration of field futsal referees affiliated with the CONCACAF Excellence Program on two different sessions. Participants visited at the same time of day (9:30–10:30 p.m.), and all the interventions were at least 48 hr. The fitness assessment session was conducted in a controlled environment, ensuring consistent temperature and humidity. Each participant completed two experimental sessions, and before the start their training sessions.

First session began with measuring participants' anthropometrical characteristic using stadiometers, sliding caliper (KAFA, Moscow, Russia), non-elastic SECA Model 200 tape and skinfold thickness was assessed using a professional ET MEASURE model SK-101 caliper (more information in anthropometric assessment section). Indeed, participants performed a familiarization with the different test of second session. In the second session (Fitness Assessment Session), participants performed a 20-meter sprint test. After the sprint test, participants underwent the CODA fitness test, which involved a series of shuttle runs requiring rapid changes in direction and the final assessment was the ARIET fitness test for three minutes, which involved a series of intermittent running exercises that mimic the movements of soccer referees during a match.

The second session, referred to as the Fitness Assessment Session, began with a standard warm-up routine pre-match to prepare the participants for the upcoming tests. Following the warm-up, the referees completed the 20-meter sprint test, which assessed their speed and acceleration. Subsequently, participants engaged in the CODA fitness test, which evaluated their agility through a series of shuttle runs requiring rapid directional changes. The final component of the Fitness Assessment Session was the ARIET fitness test, which lasted for three minutes and involved intermittent running exercises that simulated the physical demands faced by soccer referees during matches. This comprehensive assessment aimed to evaluate the participants' fitness levels, specifically targeting speed, agility, and endurance, key attributes necessary for effective performance in their roles.

All data were meticulously recorded by the lead researcher to ensure precision and reliability. The session was structured to be completed within a 90-minute timeframe, which included both warm-up and cooldown periods. Participants were encouraged to hydrate and rest adequately between tests to optimize their performance throughout the assessment.

Measures

Body composition

The physical body parameters were assessed in accordance with the standards set by the International Society for the Advancement of Kinanthropometry (ISAK). For the measurement of standing height, participants were instructed to remove their footwear and position themselves as close as possible to the stadiometer. They were required to ensure that the back of their head, scapulae, buttocks, and heels were in contact with the device while keeping their legs together. Height was recorded by aligning the measuring rod with the top of the participant's head.

Measurements were taken for various parameters: height, weight, biceps circumference, waist circumference, hip circumference, calf circumference, subscapular skinfold, triceps skinfold, suprailiac skinfold, abdominal skinfold, thigh skinfold, calf skinfold, body fat %, Fat %, and muscle mass difference for all participants. Body mass was recorded using SECA Model 217 electronic medical scales (Germany), which provide a precision of 100 grams. Diameters were measured using a sliding caliper (KAFA, Moscow, Russia), which offers a measurement accuracy of 0.1 cm. Limb circumferences were obtained with a non-elastic SECA Model 200 tape measure (Germany), ensuring a precision of 0.01 cm. Skinfold thickness was evaluated using a professional ET MEASURE model SK-101 caliper (China), which is calibrated to exert equal pressure (0.01 kg/mm²) on both sides of the fold, achieving a measurement accuracy of 0.2 mm.

20 meters sprint

It was evaluated using photocell timing gates. The evaluation system was carried out through FitLight Trainer ® sensors (Ontario, Canada) positioned at a height of 1.0 m above ground level. Each participant initiated their sprint from a self-selected standing position, located 20 cm behind the starting photocell gate, which activated a digital timer upon crossing. Following a standardized warm-up protocol, assistant referees completed two maximal 30-meter sprints, with a recovery period of three minutes between attempts to ensure optimal performance.

The starting gate was set at the 0-meter mark, while the finish gate was positioned at 20 meters, with a clearly marked start line 1.5 meters prior to the starting gate. Referees aligned themselves at the start with their front foot touching the designated start line. Upon receiving a signal from the test leader indicating that the timing system was ready, the referees commenced their sprints. A maximum recovery time of 90 seconds was permitted between the two 20-meter sprints, during which participants walked back to the starting position. In the event of a fall or trip, an additional trial was granted. If a referee failed one of the two trials, a third attempt was provided immediately after the second. Failing two out of three trials resulted in a test failure. The best sprint time (in seconds) was recorded and used for further data analysis. The average within-player performance variability was 0.06%, as indicated by the coefficient of variation.

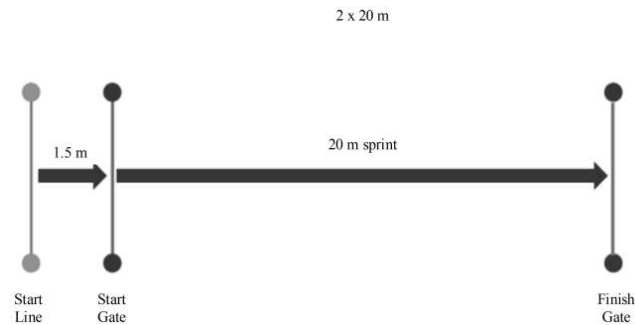


Figure 1. Protocol of 20 meters sprint test

Change of Direction Ability (CODA) fitness test

The CODA for FIFA refereeing requires a precise setup and execution to assess the agility of assistant referees effectively. The FitLight Trainer ® sensors (Ontario, Canada) was used in the present test. To begin, cones must be arranged with Cone A and Cone B positioned 2 meters apart, and Cone B and Cone C set 8 meters apart, following the specified diagram. A single timing gate should be placed at Cone A, with a 'start line' marked 0.5 meters before the timing gate. Each assistant referee will line up at the start line, ensuring their front foot touches the marked line. Once the test leader confirms that the electronic timing gates are ready, the assistant referee is free to initiate the test.

During the test, the assistant referee will sprint 10 meters forward from Cone A to Cone C, then move 8 meters sideways to the left from Cone C to Cone B, followed by 8 meters sideways to the right from Cone B back to Cone C, and finally sprinting 10 meters forward from Cone C back to Cone A. This sequence constitutes one complete trial. If an assistant referee does not meet the performance criteria, they will be allowed one additional attempt. However, if they fail to meet the criteria in both trials, they will be considered to have failed the test. This structured approach ensures a standardized assessment of agility, crucial for the performance of assistant referees in competitive matches. The CODA time (in seconds) was recorded and used for further data analysis. The average within-player performance variability was 0.04%, as indicated by the coefficient of variation.

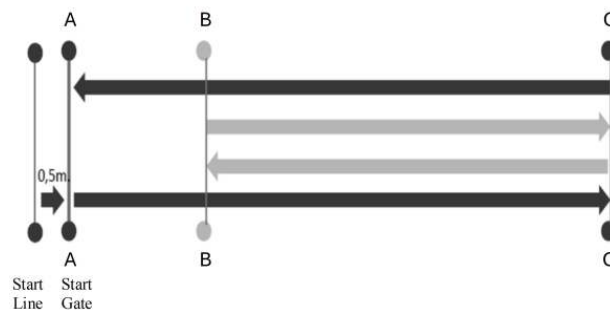


Figure 2. Protocol of CODA fitness test

Assistant Referee Intermittent Endurance Test (ARIET)

The ARIET test is a modified version of the Yo-Yo IE2 test and consists of alternating 2620 m shuttles of forwards running and 2612.5 m shuttles of sideways running at progressively increasing speeds dictated by an audio bleep emitted from a CD player (Bangsbo, 2005). The starting speed is set at 11.5 km/h for the forward running leg with the same bleep interval used for the sideways running (2 shuttles). Speed increments for the forward running legs are provided in reason of 1 km/h for the first three stages (2 shuttles per stage). After a successive 0.5 km/h speed increment (8 shuttles) pace increased by 0.25 km/h to exhaustion every 3–8 shuttles per stage. Between the shuttles the assistant referees have a 5-s period of forwards jogging around a marker placed 2.5 m behind the finishing line. Failure to achieve the shuttle run in time on two occasions results in termination of the test and the distance covered in the last complete successful shuttle is recorded and represents the test result. The test lasted for 8–20 min for assistant referees in the present study, corresponding to 495 and 1795 m. The test was performed according to the procedures suggested by (Krustrup et al., 2003) with speeds dictated by an audio bleep emitted from a CD player. The total distance (in meters) completed was recorded for further data analysis. The average within-player performance variability was 0.01%, as indicated by the coefficient of variation.

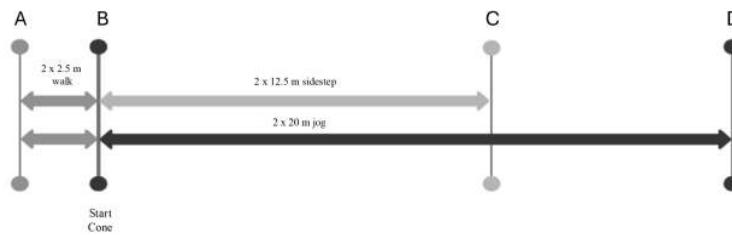


Figure 3. Protocol of ARIET fitness test

Statistical Analysis

Descriptive statistics were calculated for each variable. Normal distribution and homogeneity tests (Kolmogorov–Smirnov and Levene’s, respectively) were conducted on all metrics. A t-test analysis was performed to observe the differences anthropometrical measures (Age, height, weight, biceps circumference, Waist circumference, hip Circumference, Calf Circumference, Subscapular skinfold, Triceps skinfold, Suprailiac skinfold, Abdominal skinfold, Thigh skinfold, calf skinfold, body fat %, Fat %, and Muscle Mass difference) and Physical fitness test (20-meter sprint test, CODA fitness test and ARIET fitness test) between LEPFR and HEPFR. The standardized Cohen’s *d* was calculated as a measure of effect size, using the following thresholds: 0.0-0.2 (trivial), 0.2-0.6 (small), 0.6-1.2 (moderate), 1.2-2.0 (large), and >2.0 (very large). Subsequently, Pearson’s correlation coefficient *r* was used to examine the relationship between the anthropometrical measures (Age, height, weight, biceps circumference, Waist circumference, hip Circumference, Calf Circumference, Subscapular skinfold, Triceps skinfold, Suprailiac skinfold, Abdominal skinfold, Thigh skinfold, calf skinfold, body fat %, Fat %, and Muscle Mass difference) and Physical fitness test (20-meter sprint test, CODA fitness test and ARIET fitness test). We adopted the following criteria to interpret the magnitude of these correlations: $r \leq 0.1$, trivial; $0.1 < r \leq 0.3$, small; $0.3 < r \leq 0.5$, moderate; $0.5 < r \leq 0.7$, large; $0.7 < r \leq 0.9$, very large; and $r > 0.9$, almost perfect. Following the correlation analysis, we created a graphical representation to further clarify the relationships among the significant variables. Specifically, a three-dimensional surface plot was generated to illustrate the relations between i) 20-meter sprint test, ii) CODA fitness test and iii) ARIET fitness test body (refer to Figure x for detailed visualization). All analysis were conducted using statistical software Statistica (version 13.1; Statsoft, Inc., Tulsa, OK, USA) and the significance level was set at $p < 0.05$.

Results

Table 1 shows the physical body parameters and physical fitness test results. A paired sample *t*-test was used for determining differences between YPSP and HEPFR. The *t*-test analysis revealed notable differences in various anthropometric parameters between the groups, including body weight ($p = 0.05$; $d = 0.73$, moderate effect size), fat mass in kg ($p = 0.05$; $d = 0.74$, moderate effect size), and skinfold thickness at subscapular ($p = 0.001$; $d = 0.49$, small effect size), triceps ($p = 0.001$; $d = 0.71$, moderate effect size), and abdominal sites ($p = 0.05$; $d = 0.44$, small effect size). HEPFR group exhibited superior values in these metrics, suggesting that a more favorable body composition may enhance their performance (See Figure 4, 5, 6, 7, for more information).

Table 1. Physical body parameters and physical fitness test of the SRs ($n = 22$)

	LEPFR ($n=11$)	HEPFR ($n=11$)	Total	<i>t</i> -test	
	Mean $\pm$ SD	Mean $\pm$ SD	t-test	<i>p</i>	Cohen <i>d</i>
Body composition					
Height (cm)	173.90 $\pm$ 7.06	170.45 $\pm$ 6.23	172.18 $\pm$ 6.73	.28	.52
Body weight (kg)	70.73 $\pm$ 8.24	63.87 $\pm$ 10.51	67.30 $\pm$ 9.86	.05*	.73
% Body fat (Kg)	12.71 $\pm$ 2.61	10.57 $\pm$ 3.52	11.64 $\pm$ 3.21	.08	.69
Kg fat (Kg)	9.03 $\pm$ 2.31	6.96 $\pm$ 3.18	7.99 $\pm$ 2.91	.05*	.74
Muscle Mass Difference (Kg)	61.70 $\pm$ 7.03	56.91 $\pm$ 7.87	59.30 $\pm$ 7.87	.12	.63
Circumferences					
Biceps (cm)	29.82 $\pm$ 3.60	29.09 $\pm$ 3.05	29.45 $\pm$ 3.28	0.29	.22
Waist (cm)	80.18 $\pm$ 7.03	80.18 $\pm$ 8.45	80.18 $\pm$ 7.58	0.09	.00
Hip (cm)	96.09 $\pm$ 4.95	90.45 $\pm$ 5.82	93.27 $\pm$ 6.01	0.69	1.04
Calf (cm)	35.09 $\pm$ 2.43	34.00 $\pm$ 2.72	34.55 $\pm$ 2.58	0.27	.42
Skinfolds					
Subscapular (mm)	12.11 $\pm$ 2.11	11.06 $\pm$ 2.13	11.59 $\pm$ 2.14	.001**	.49
Triceps (mm)	11.74 $\pm$ 4.77	8.61 $\pm$ 4.04	10.17 $\pm$ 4.60	.001**	.71
Suprailiac (mm)	14.48 $\pm$ 7.39	13.23 $\pm$ 10.84	13.85 $\pm$ 9.08	.08	.14
Abdominal (mm)	26.95 $\pm$ 7.49	21.82 $\pm$ 14.66	24.39 $\pm$ 11.66	.05*	.44
Thigh (mm)	17.94 $\pm$ 7.57	10.77 $\pm$ 5.29	14.35 $\pm$ 7.35	.12	1.10
Calf (mm)	10.23 $\pm$ 4.60	5.98 $\pm$ 2.13	8.10 $\pm$ 4.11	.09	1.19
Physical Fitness test					

Sprint test (sec)	2.98±0.12	2.91±0.21	2.94±0.17	.24	.39
CODA (sec)	9.78±0.30	9.59±0.30	9.68±0.43	.27	.45
ARIET (m)	1331.36±51.04	1318.18±81.71	1324.77±66.82	.50	-.16
VO2max (ml·kg ⁻¹ ·min ⁻¹)	47.59±0.43	47.47±0.52	47.59±0.40	.52	.19

Note: LEPFR: Lower Expertise Professional Futsal Referees; HEPFR: Higher Expertise Professional Futsal Referees; ARIET: Assistant Referee Intermittent Endurance Test; CODA: Change of Direction Ability fitness VO2max: maximal oxygen consumption * Denotes significance at $p < 0.05$. and ** denotes significance at $p < 0.01$

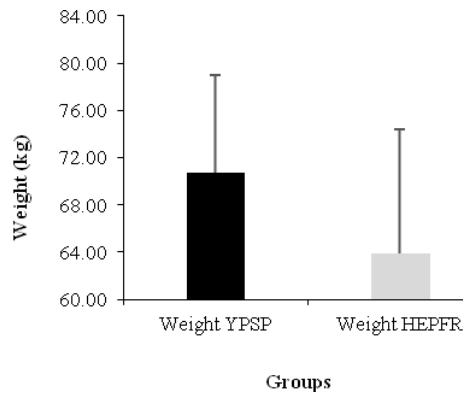


Figure 4. Differences in body weight between YPSP and HEPFR

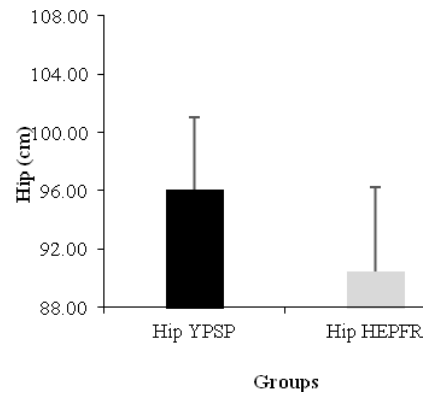


Figure 5. Differences in Hip Circumference between YPSP and HEPFR

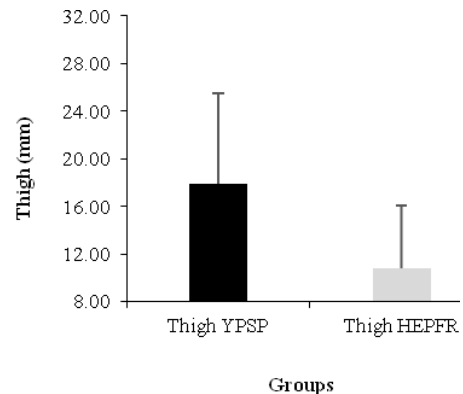


Figure 6. Differences in skinfolds thigh between YPSP and HEPFR

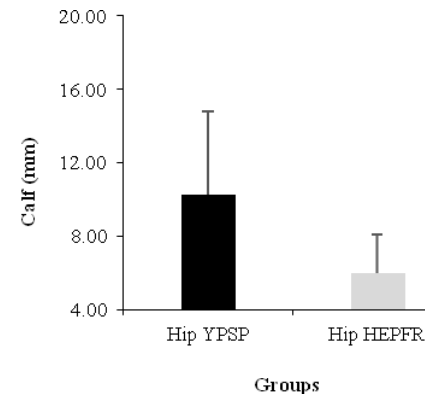


Figure 7. Differences in skinfolds calf between YPSP and HEPFR

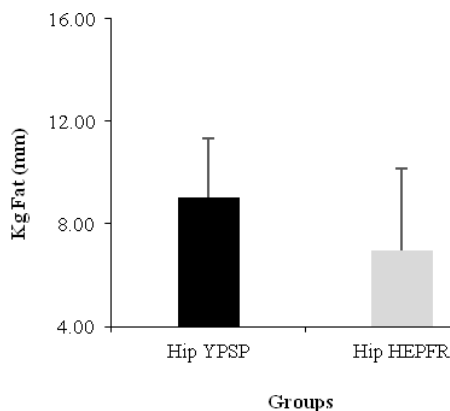
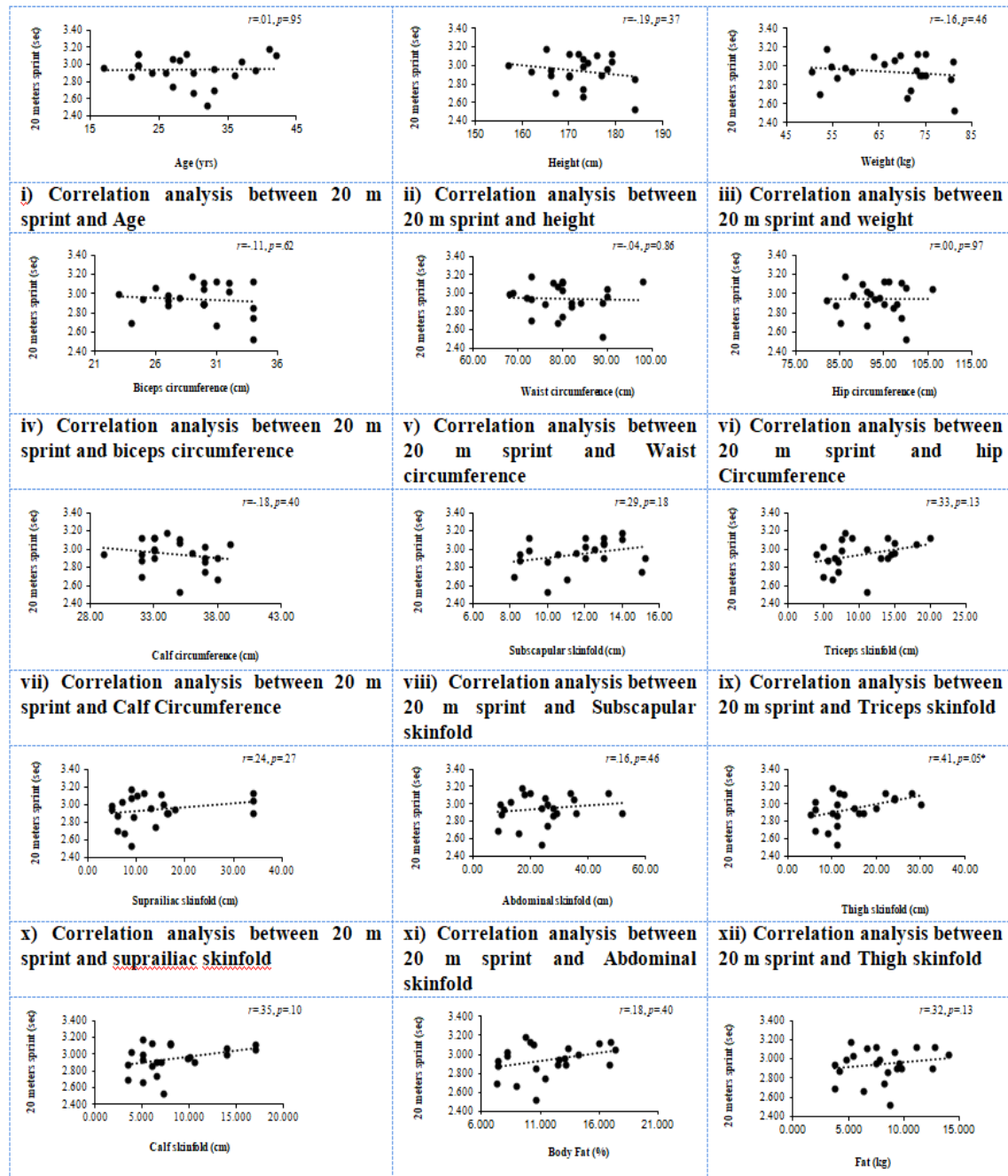


Figure 8. Differences in Kg Fat thigh between YPSP and HEPFR

Correlation analyses were performed to examine the relationships between 20-meter sprint test, CODA fitness test, and ARIET fitness test, alongside anthropometric measurements. The results indicated a small but significant positive correlation between the 20-meter sprint test and thigh circumference, with a moderate correlation coefficient of $r = 0.41$ ($p = 0.05$). Similarly, a moderate inverse correlation was observed between

bicep circumference and the CODA fitness test, reflected by a moderate coefficient of $r = -0.43$ ($p = 0.05$). Furthermore, a strong positive correlation was identified between the CODA fitness test and thigh circumference, with a large coefficient of $r = 0.57$ ($p = 0.05$). Notably, no significant correlations were found with the ARIET fitness test. These results suggest that specific anthropometric measures, particularly thigh circumference, are positively associated with certain physical fitness tests, while bicep circumference appears to have a negative relationship with the CODA fitness test. This highlights the importance of considering body composition and measurements when evaluating physical fitness, as they may influence performance outcomes in various fitness assessments. Further research is warranted to explore these relationships in greater depth and to understand their implications for fitness training and assessment (See Figure 9, 10 and 10, for more information).



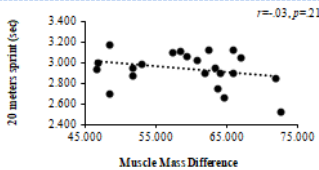
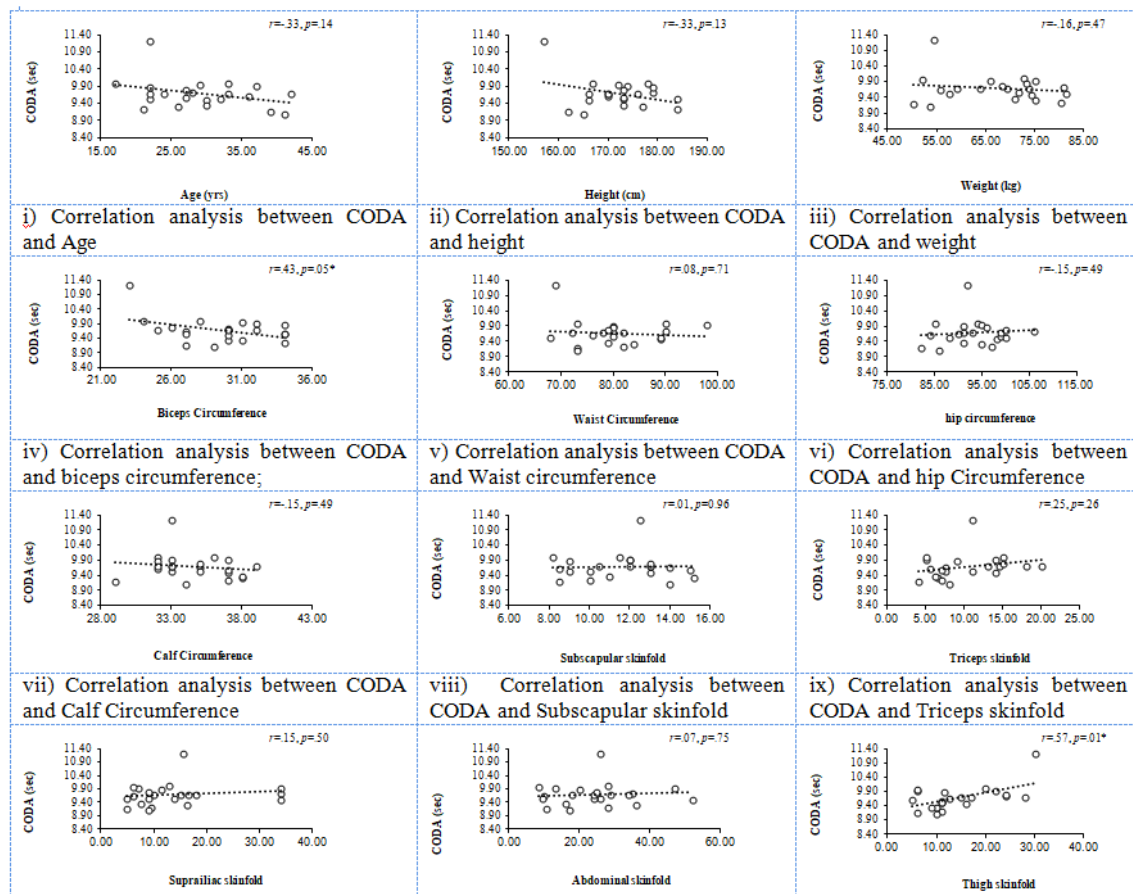
xiii) Correlation analysis between 20 m sprint and calf skinfold 	xiv) Correlation analysis between 20 m sprint and body fat %	xv) Correlation analysis between 20 m sprint and Fat %
xvi) Correlation analysis between 20 m sprint and Age		

Figure 9. Correlation analysis between 20 m sprint and Anthropometric measures:

- i) Correlation analysis between 20 m sprint and Age;
- ii) Correlation analysis between 20 m sprint and height;
- iii) Correlation analysis between 20 m sprint and weight;
- iv) Correlation analysis between 20 m sprint and biceps circumference;
- v) Correlation analysis between 20 m sprint and Waist circumference;
- vi) Correlation analysis between 20 m sprint and hip Circumference;
- vii) Correlation analysis between 20 m sprint and Calf Circumference;
- viii) Correlation analysis between 20 m sprint and Subscapular skinfold;
- ix) Correlation analysis between 20 m sprint and Triceps skinfold;
- ix) Correlation analysis between 20 m sprint and suprailiac skinfold;
- x) Correlation analysis between 20 m sprint and Abdominal skinfold;
- xi) Correlation analysis between 20 m sprint and Thigh skinfold;
- xii) Correlation analysis between 20 m sprint and calf skinfold;
- xiii) Correlation analysis between 20 m sprint and body fat %;
- xv) Correlation analysis between 20 m sprint and Fat %, and
- xvi) Correlation analysis between 20 m sprint and Muscle Mass difference



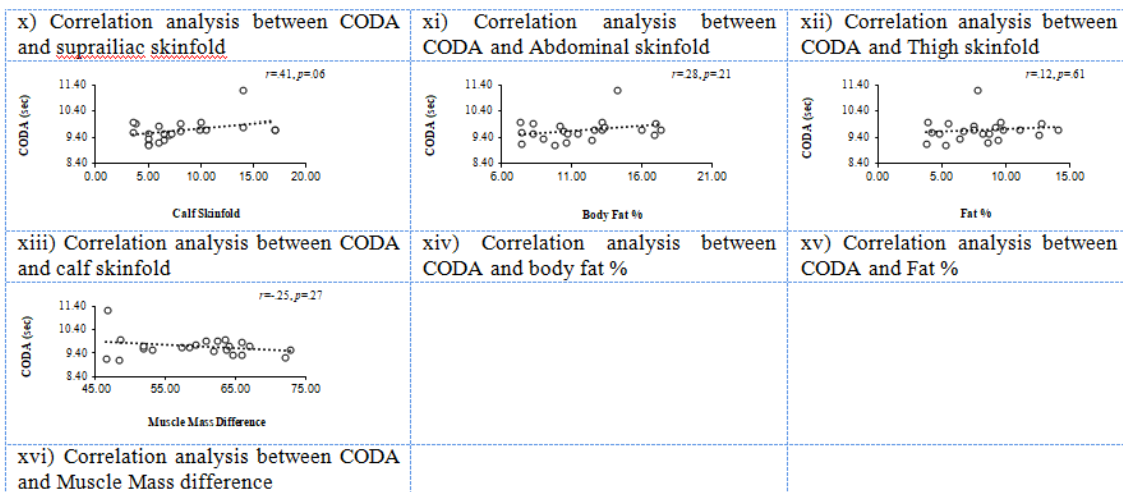
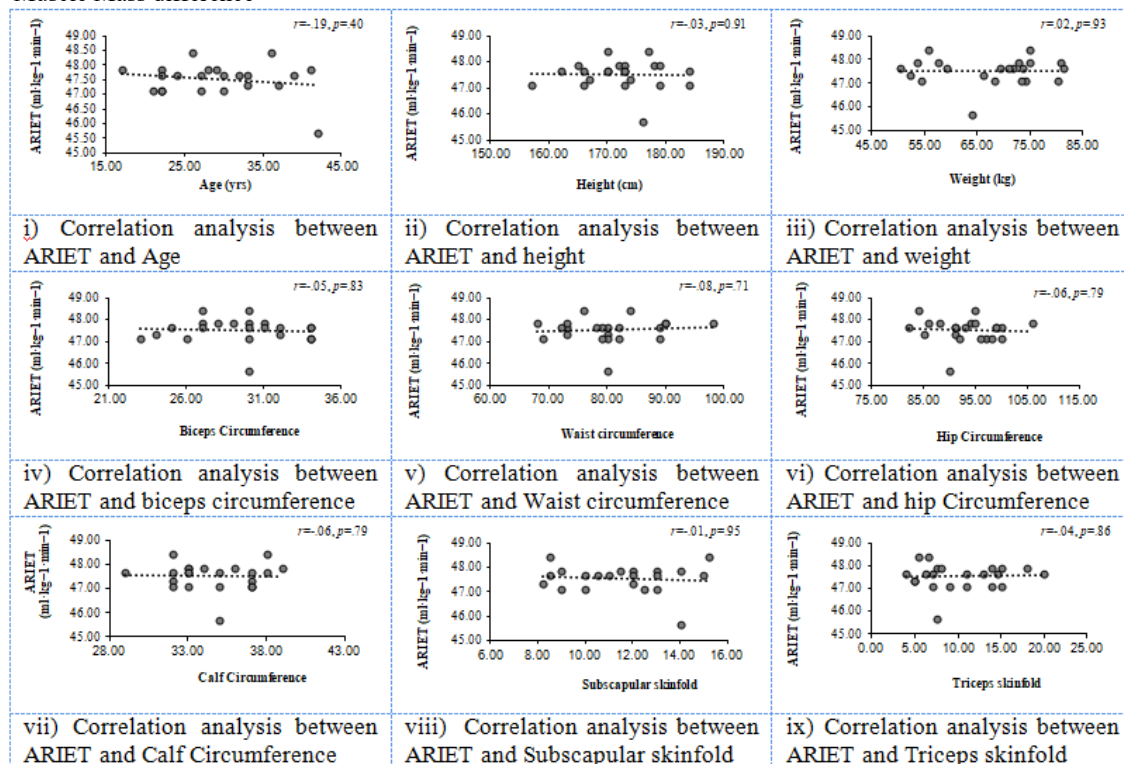


Figure 10. Correlation analysis between CODA and Anthropometric measures:

- i) Correlation analysis between CODA and Age;
- ii) Correlation analysis between CODA and height;
- iii) Correlation analysis between CODA and weight;
- iv) Correlation analysis between CODA and biceps circumference;
- v) Correlation analysis between CODA and Waist circumference;
- vi) Correlation analysis between CODA and hip Circumference;
- viii) Correlation analysis between CODA and Subscapular skinfold;
- ix) Correlation analysis between CODA and Triceps skinfold;
- x) Correlation analysis between CODA and suprailiac skinfold;
- xi) Correlation analysis between CODA and Abdominal skinfold;
- xii) Correlation analysis between CODA and Thigh skinfold;
- xiv) Correlation analysis between CODA and calf skinfold;
- xv) Correlation analysis between CODA and body fat %;
- xv) Correlation analysis between CODA and Fat %, and xvi) Correlation analysis between CODA and Muscle Mass difference



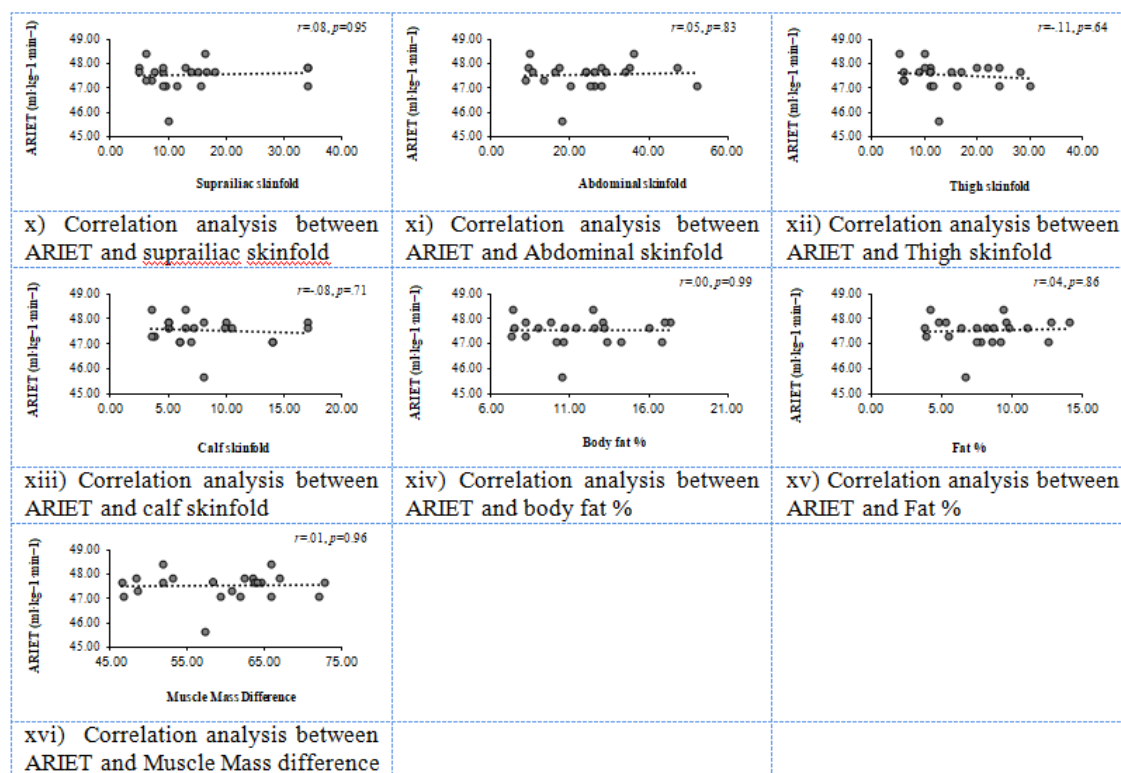


Figure 11. Correlation analysis between ARIET and Anthropometric measures: i) Correlation analysis between ARIET and Age; ii) Correlation analysis between ARIET and height; iii) Correlation analysis between ARIET and weight; iv) Correlation analysis between ARIET and biceps circumference; v) Correlation analysis between ARIET and Waist circumference; vi) Correlation analysis between ARIET and hip Circumference; vii) Correlation analysis between ARIET and Calf Circumference; viii) Correlation analysis between ARIET and Subscapular skinfold; ix) Correlation analysis between ARIET and Triceps skinfold; x) Correlation analysis between ARIET and suprailiac skinfold; xi) Correlation analysis between ARIET and Abdominal skinfold; xii) Correlation analysis between ARIET and Thigh skinfold; xiii) Correlation analysis between ARIET and calf skinfold; xiv) Correlation analysis between ARIET and body fat %; xv) Correlation analysis between ARIET and Fat %, and xvi) Correlation analysis between ARIET and Muscle Mass difference

Discussion

The present study aimed to investigate differences in body composition and physical fitness assessments between LEPFR and HEPFR. By analyzing these physical attributes, the research sought to illuminate the specific physical demands associated with futsal officiating and explore potential correlations among these measures. The results revealed significant differences in anthropometric characteristics, including body weight, fat mass, and skinfold thickness at subscapular, triceps, and abdominal sites. The HEPFR group consistently showed more favorable values in these metrics (lower values), suggesting that a more advantageous body composition may contribute to superior performance. These findings highlight the importance of understanding how physical attributes, such as body composition, influence refereeing effectiveness in futsal and emphasize the need for tailored training and selection strategies to optimize referee performance.

Numerous studies emphasize the critical role of body composition in athletic performance. For example, research by Helsen and Bultynck (2004) indicates that elite referees with superior physical conditioning and body composition are more effective during matches. Additionally, a study by Bülent Okan et al. (2017) supports the idea that optimal body composition is linked to better performance outcomes among sports officials. Furthermore, a review by Giske et al. (2016) highlights the importance of physical fitness and body composition in decision-making and performance under pressure in sports contexts. Crucially, age and experience play a significant role in the performance and effectiveness of referees in futsal and other sports. As referees gain experience, they develop a deeper understanding of the game, improve their decision-making skills, and enhance their ability to manage high-pressure situations. Research indicates that older referees often exhibit greater composure and confidence, which can lead to more accurate judgments during matches (González-Oya & Dosil, 2004). Additionally, experienced referees are better equipped to handle the dynamics of player interactions and game flow, ultimately contributing to a more seamless officiating process (Diotaiuti et al., 2017). The findings of this study align with these insights, as the HEPFR group exhibited superior values in body composition and

fitness metrics, reinforcing the notion that experience, and age contribute positively to refereeing performance. Therefore, fostering the development of younger referees through mentorship and training is essential for cultivating future talent in the sport.

Given the fast-paced nature of futsal, referees require quick decision-making and rapid movement, necessitating a strong fitness profile. Correlation analyses revealed significant relationships between specific anthropometric measurements and fitness assessments. Notably, a positive correlation between thigh circumference and the 20-meter sprint and CODA fitness tests highlights the influence of lower body composition on speed and agility. In contrast, a moderate inverse correlation between bicep circumference and the CODA test suggests that upper body measurements may be less beneficial for agility tasks. The lack of significant correlations with the ARIET fitness test indicates that different fitness components may be influenced by distinct physical attributes. These findings underscore the value of incorporating anthropometric assessments into fitness evaluations to inform targeted training strategies.

In this respect, the present research tries to elucidate the intricate relationship between anthropometric measurements and fitness performance among professional futsal referees. A significant positive correlation was observed between thigh circumference and performance on the 20-meter sprint test, underscoring the importance of lower body composition in enhancing speed and agility, essential attributes for effective officiating in the fast-paced environment of futsal. This finding aligns with previous research associating greater thigh circumference, indicative of greater muscle mass and strength in the quadriceps and hamstrings, with greater sprinting ability (Brocherie et al., 2014; Bex et al., 2017). However, Nuell et al. (2021) consider that there is no scientific clarity on the relationship between the quadriceps muscle and sprint performance. The studies by González-Ortega et al. (2023) and Castillo-Rodríguez et al. (2023) underline the importance of sprint actions in football referees during matches, as these allow them to position themselves optimally to monitor the various plays on the pitch. This observation is equally applicable to the context of futsal referees, as they share similar physical demands related to agility and reactivity.

Conversely, the lack of correlation between bicep circumference and sprint performance ($r=-.11$, $p=.62$) suggests that upper body metrics may not exert a substantial influence on agility. Nuell et al. (2021) consider that upper body strength can improve running efficiency through enhanced arm movement the current findings indicate a more complex relationship. Additionally, the weak negative correlation between calf circumference and sprint times ($r=-.18$, $p=.40$) suggests that, although calf muscles contribute to propulsion, their impact is likely overshadowed by the more pronounced effects of thigh musculature.

The ability to execute COD is critical in numerous sports, necessitating rapid adjustments in movement patterns. The CODA test serves as an effective measure of an athlete's agility and responsiveness, with anthropometric factors such as thigh, bicep, and calf circumferences potentially influencing performance outcomes. Research has demonstrated a positive correlation between thigh circumference and COD performance ($r = 0.57$, $p = 0.05$), indicating that increased muscle mass in the thighs enhances force generation for swift directional changes. In contrast, the relationship between calf circumference and COD performance ($r=-.15$, $p=.49$) remains less clear; while robust calf muscles contribute to overall agility, their direct impact on performance is ambiguous. Several authors highlight the critical role of referees on the field, emphasizing the necessity of maintaining optimal physical fitness to perform tasks such as changing direction, sprinting, and positioning themselves as close as possible to the various actions occurring during gameplay (González-Ortega et al., 2023). This assessment is equally applicable to futsal referees, as the nature of the game demands rapid decision-making and frequent high-intensity movements in a smaller playing area, requiring exceptional agility, reaction time, and sprinting ability to keep up with the pace of play.

Upper body strength, particularly in the biceps, also plays a role in agility. Although not directly related to lower-body movements, effective arm mechanics can enhance stability and coordination during COD. A moderate correlation ($r = 0.43$, $p = 0.05$) between upper body strength and COD performance underscores the importance of a comprehensive training regimen that integrates both upper and lower body strength development. In this regard, Nygaard Falch et al. (2020) suggest that muscular activity is one of the factors directly contributing to performance in explosive dynamic movements such as COD. Most studies, however, focus on correlating COD performance with major lower limb muscle groups, emphasizing the force production of hip flexors, knee extensors, and plantar flexors.

The present study has several strengths and limitations in analyzing the anthropometric and fitness parameters of professional futsal referees affiliated with the CONCACAF Excellence Program. A key strength is the use of a professional referee sample, which enhances the validity and relevance of the findings in the context of high-level officiating. This elite cohort allows for a more accurate assessment of the critical role physical fitness plays in officiating fast-paced futsal competitions, where quick decision-making and rapid movement are essential. The study identified significant correlations between specific anthropometric measurements, particularly thigh circumference, and performance in fitness assessments such as the 20-meter sprint and CODA tests. These findings highlight the importance of lower body composition in enhancing speed and agility, vital attributes for referees. Additionally, the inclusion of a three-dimensional surface plot visually represents the

interactions among fitness tests, serving as a valuable tool for coaches and trainers to optimize training regimens based on observed relationships. However, the study also has limitations. The sample size, while professional, may not represent all futsal referees, potentially affecting the generalizability of the findings. Furthermore, the lack of significant correlations with the ARIET fitness test suggests that not all relevant fitness components were captured, indicating a need for a more comprehensive approach. Lastly, while the study emphasizes anthropometric assessments, it does not explore the impact of other factors, such as training history or psychological aspects, on performance, which could provide a more holistic understanding of athletic capabilities.

The findings of the present study carry significant practical implications for the training and development of professional futsal referees, particularly addressing the challenges faced by younger officials. By emphasizing the importance of specific anthropometric measurements, especially thigh circumference, in enhancing speed and agility, the study lays the groundwork for tailored fitness programs designed to improve officiating performance. Coaches and trainers can leverage these insights to create training regimens that prioritize lower body strength and power, which are crucial for quick movements and effective decision-making during fast-paced matches. Moreover, the moderate inverse correlation identified between bicep circumference and agility performance suggests that training programs should focus more on lower body conditioning rather than upper body strength for referees. This is particularly relevant for younger referees, who may struggle with agility and speed due to insufficient lower body development. Incorporating regular anthropometric assessments into fitness evaluations will enable referees to better monitor their physical capabilities and make informed adjustments to their training strategies. Ultimately, these practical applications aim to enhance the overall fitness and performance of futsal referees, particularly the younger cohort, ensuring they are well-prepared to meet the demands of high-level competitions. By focusing on these targeted goals, the training programs can help young referees improve their officiating skills and contribute positively to the integrity of the sport.

Conclusions

In conclusion, this study analyzed the anthropometric and fitness parameters of professional futsal referees in the CONCACAF Excellence Program, highlighting the critical role of physical fitness in officiating. Significant correlations were found between thigh circumference and performance in the 20-meter sprint and CODA fitness tests, emphasizing the importance of lower body composition for speed and agility. Conversely, the moderate inverse correlation between bicep circumference and the CODA test suggests that upper body measurements may not enhance agility performance. The absence of significant correlations with the ARIET fitness test indicates that different fitness components are influenced by distinct physical attributes. These findings advocate for integrating anthropometric assessments into fitness evaluations to optimize training strategies. Future research should explore these relationships further, focusing on their implications for athletic training and the development of tailored regimens for futsal referees and athletes.

Competing interests. The authors declare that they have no competing interests.

Funding: The present study was funded by the Unit of Excellence at the University Campus of Melilla (University of Granada, Spain). Reference: UCE-PP2024-02.

Data Availability Statement: The data supporting the findings of this study can be obtained from the corresponding author upon reasonable request.

Acknowledgements: We sincerely thank the professional futsal referees and the CONCACAF for their invaluable cooperation and active participation in this study. Their willingness to collaborate was instrumental in the successful completion of this research. FTGF gratefully acknowledges that is supported by Beca de Movilidad Erasmus+ for teaching (PDI) Erasmus 2023–2024.

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