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Anthropometric characteristics of young elite sailors based on performance level☆

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A B S T R A C T

Background: /Objectives: The aim of the present study was to analyse possible differences in anthropometric characteristics of elite sailors based on categories and performance level.
Methods: : A total of 42 young (aged 12–18 years) elite sailors (men = 31; women = 11) of the Monohull (n = 21) and Windsurfing (n = 21) categories composed the study sample. Testing was per-formed in one session the day before the start of an official and international competition. Body composition was measured using an octopolar and multi-frequency electrical bioimpedance analyser, and height was recorded using a telescopic measuring instrument. Cross-sectional study. The total sample was divided into two groups based on their performance level (ranking), 50th percentile (P1), and 100th percentile (P2).
Results: : P1 presented a lower BMI, total body fat mass, and body fat mass in the trunk, arms, and legs ($p < 0.05$). Similarly, P1 reported a higher total body muscle mass and body muscle mass on the trunk, arms, and legs compared to the less level performance group ($p < 0.05$). In addition, P2 sailors were taller and heavier ($p < 0.05$). Regarding categories, the Windsurf sailors presented statistically significantly lower arm fat mass than the Monohull ($p < 0.05$). The Windsurf sailors showed differences between the two performance-level groups ($p < 0.05$). Additionally, comparing the high-level performance group in both categories, higher arm muscle mass on the Windsurfing sailors was detected ($p < 0.05$).
Conclusions: : These findings could help to differentiate the anthropometric variables that determine sport performance in young elite sailors and could be used to differentiate the anthropometric variables in each category.

1. Introduction

Among the different classes of sailing sports, the Laser Radial, Laser 4.7 and 420 classes are in the Monohull category and the Techno 2.93 and RS:X classes are in the Windsurfing category. Laser Radial and RS:X are Olympic sailing classes since 1996 and 2016, respectively.

In dinghy sailing, the navigation format has changed by the development of the physical and physiological requirements of the sailor, such as muscular strength, muscular endurance and cardiorespiratory performance.[1] Different studies have analysed the sailor's physical fitness,[2] biomechanics factor[3] and physiological demands,[4] according to performance level. Anthropometry is used as a reference in sports performance.[5] Moreover, the anthropometric and somatotype profiles are related to performance in

☆ The study was conducted according to the guidelines of the Declaration of Helsinki and was approved by the Ethics Committee of the Alfonso X El Sabio University.

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dinghy sailing.[6,7] Some studies have shown the relationship between performance and anthropometric variables, such as having greater body mass, height, thigh length and body mass index (BMI).[8,9] The results of these studies show that the most successful sailors have these anthropometric characteristics and they can facilitate a specific technical gesture called *hiking bench*.[9] The main aim of this technical gesture is to overcome the forces that are generated by the effect of the wind, where the body is used as a lever arm.[10] Thus, the greater the body mass, height, thigh length and BMI, the more lever arm can be developed by the sailor. In fact, the anthropometric assessment would be important for choosing between one or another sailing class, since optimal anthropometric requirements differ among boat/board classes.[11]

Over the years, the anthropometric characteristics of athletes have changed, and this has led to numerous changes in the sporting context. Thus, reference bases should be updated every so often. In different sports disciplines, studies have shown the relationship between sports performance and anthropometric characteristics.[12–14] However, most studies are not focused on analysing this relationship, although, in the case of sailing, most of studies provide relevant information on the anthropometric characteristics of sailors.[4,7–9,15–20] Therefore, the aim of our study was to determine the anthropometric characteristics of elite sailors in the Monohull and Windsurfing categories and their differences based on performance level.

2. Methods

2.1. Subjects

The study sample consisted of 42 sailors (31 men and 11 women) of the Monohull and Windsurfing categories. The Monohull category group was composed of 21 sailors of the Laser ($n = 15$) and the 420 ($n = 6$) classes. The Windsurfing category group was composed of 21 sailors of the Techno-293 ($n = 12$) and RS:X ($n = 9$) classes. The age range of the sailors was 12–18 years. All participants, their parents and their coaches were contacted by email and were invited to participate in the study. All sailors gave their informed consent and were given information concerning the study. This investigation was approved by the Ethics Committee of the Alfonso X El Sabio University.

2.2. Experimental desing

Testing was performed in one session the day before the start of the competition. For the data collection, a room was set up at the headquarters of the Andalusian Sailing Federation, and a schedule was established for the sailors to attend the measurements. Previously, and to facilitate the process, the shifts to access the room were completed with the trainers. Weight, fat mass (total body, trunk, arms and legs) and muscle mass (total body, trunk, arms and legs) were measured using an octopolar and multi-frequency electrical bioimpedance analyser (Tanita MC 780-P MA, Tanita Europe, Sindelfingen, Germany) to the nearest 0.1 kg. The participants wore only underwear and a T-shirt. Height was measured barefooted, using a telescopic height measuring instrument (Leicester Tanita HR001 stadiometer, Tanita Europe, Sindelfingen, Germany) to the nearest 0.1 cm.

2.3. Regatta

The analysed regatta was the XV New Year's Race in El Puerto de Santa María (Cádiz, Spain, 2018). It was an official and international competition, in which a total of 113 sailors competed. The total sample, Monohull and Windsurfing categories, was divided into two groups based on their performance level (ranking), differentiating the best athletes as those who were within the 50th percentile (P1) from those within the 100th percentile (P2).

2.4. Statistical analysis

The data are presented as mean (M) ± standard deviation (SD). A Kolmogorov-Smirnoff test was performed to verify that all the variables were adjusted to the normal distribution, whereas a Levene's test confirmed homoscedasticity. A two-factor analysis of variance (ANOVA) was performed considering category (Monohull vs. Windsurfing) and performance (P1 vs. P2) as independent variables. In the pairwise comparison, the Bonferroni post-hoc test was used. In addition, partial eta squared (η_p^2) was calculated considering the effect sizes (ES) as small (<0.25), medium (0.26–0.63) and large (>0.63). Statistical differences were set up at $p < 0.05$. All the statistical analyses were calculated using the Statistical Package for Social Sciences software (version 18.0, SPSS Inc., Chicago, IL, USA).

3. Results

No differences were observed in the age of the participants in terms of category ($F = 0.008$; $p = 0.928$; $\eta_p^2 = 0.159$), performance ($F = 3.170$; $p = 0.086$; $\eta_p^2 = 0.105$) or category·performance ($F = 1.922$; $p = 0.177$; $\eta_p^2 = 0.066$); however, in Windsurfing, the P1 sailors were older than the P2 sailors ($p = 0.034$) (see Table I). Regarding weight, statistical differences were detected in performance ($F = 14.667$; $p = 0.001$; $\eta_p^2 = 0.352$), but not in category ($F = 1.225$; $p = 0.278$; $\eta_p^2 = 0.043$) or category·performance ($F = 0.201$; $p = 0.657$; $\eta_p^2 = 0.007$). Therefore, the P1 sailors were heavier than the P2 sailors in both Monohull ($p = 0.024$) and Windsurfing ($p = 0.005$). With respect to height, differences were also identified in performance ($F = 18.593$; $p < 0.001$; $\eta_p^2 = 0.408$), but not in category ($F = 3.119$; $p = 0.089$; $\eta_p^2 = 0.104$) or performance·category ($F = 1.645$; $p = 0.211$; $\eta_p^2 = 0.057$). Therefore, the P1 sailors were taller than the P2 sailors in both Monohull ($p = 0.041$) and Windsurfing ($p = 0.001$), and the P1 Monohull sailors were taller than the P1 Windsurfing sailors ($p = 0.026$). Regarding BMI, no differences were found in category ($F = 0.380$; $p = 0.543$; $\eta_p^2 = 0.014$) or performance·category ($F = 0.015$; $p = 0.904$; $\eta_p^2 = 0.001$), although differences were observed in performance, with a lower value in P1 sailors compared to P2 sailors ($F = 7.192$; $p = 0.012$; $\eta_p^2 = 0.210$).

In the analysis of body fat, differences were observed in performance (P1 = 15.61 ± 2.77% vs. P2 = 20.42 ± 5.29%; $F = 11.255$; $p = 0.002$; $\eta_p^2 = 0.294$), but not in category ($F = 1.343$; $p = 0.257$; $\eta_p^2 = 0.047$) or performance·category ($F = 0.005$; $p = 0.944$; η_p^2 <0.001). Therefore, P2 sailors had greater body fat mass than P1 sailors in Monohull (P1 = 16.42 ± 2.02% vs. P2 = 21.28 ± 4.32%; $p = 0.028$) and in Windsurfing (P1 = 14.60 ± 3.36% vs. P2 = 19.67 ± 5.40%; $p = 0.023$) (see Fig. 1).

Distribution of body fat mass on the trunk, arm and leg segments are presented in Table II. The results reported no differences in trunk ($F = 2.428$; $p = 0.131$; $\eta_p^2 = 0.082$) or legs ($F = 0.020$; $p = 0.888$; $\eta_p^2 = 0.001$) between categories or performance·category ($p > 0.05$). On the other hand, differences were found in arms, with a higher fat mass in Monohull sailors than in Windsurfing sailors ($F = 4.577$; $p = 0.042$; $\eta_p^2 = 0.145$). With regard to performance, differences were detected in trunk ($F = 12.647$;

Table 1
Results of age, height, weight, and body mass index of the sailors according to category and performance.

Variable	Category	Performance		
		50th percentile (P1)	100th percentile (P2)	Total
Age (years)	Monohull	18.00 ± 0.67	18.17 ± 1.47	18.06 ± 1.00
	Windsurfing	17.37 ± 1.51 *	18.71 ± 0.95 *	18.00 ± 1.41
	Total	17.72 ± 1.13	18.46 ± 1.20	18.03 ± 1.20
Height (cm)	Monohull	172.59 ± 5.67 *· λ	179.30 ± 7.41 *	175.10 ± 6.99
	Windsurfing	165.84 ± 6.06 *· λ	178.23 ± 5.33 *	171.62 ± 8.45
	Total	169.59 ± 6.64 *	178.72 ± 6.12 *	173.42 ± 7.80
Weight (kg)	Monohull	62.07 ± 8.88 *	75.48 ± 10.92 *	67.10 ± 11.49
	Windsurfing	55.90 ± 7.22 *	72.87 ± 15.86 *	63.82 ± 14.51
	Total	59.33 ± 14.51 *	74.08 ± 13.32 *	65.51 ± 12.93
Body mass index (kg/m^2)	Monohull	20.74 ± 2.05	23.52 ± 3.33	21.78 ± 2.85
	Windsurfing	20.25 ± 1.56	22.79 ± 3.83	21.43 ± 3.04
	Total	20.52 ± 1.81 *	23.12 ± 3.48 *	21.61 ± 2.90

Data presented as M ± SD. Statistical differences fixed at $p < 0.05$.λ
* Statistical differences between sailors of different performance in the same category of sailing.
λ Statistical differences between sailors of different categories in the same performance group.

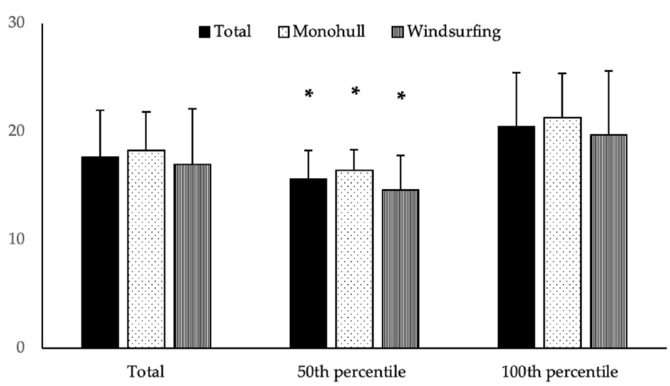

Fig. 1. Body fat mass (expressed as percentage) of the sailors according to category and performance.
Data presented as M ± SD. Statistical differences fixed at $p < 0.05$. *: statistical differences between sailors of different performance in the same category of sailing.

$p = 0.001$; $\eta_p^2 = 0.319$), arms ($F = 9.012$; $p = 0.006$; $\eta_p^2 = 0.250$) and legs ($F = 6.343$; $p = 0.018$; $\eta_p^2 = 0.190$), with higher levels of body fat in P2 sailors compared to P1 sailors.

In the analysis of muscle mass, statistically significant differences were observed in performance, with a higher body muscle mass in P1 sailors compared to P2 sailor for the total sample (P1 = 80.22 ± 0.91% vs. P2 = 75.55 ± 1.07%; $F = 11.083$; $p = 0.003$; $\eta_p^2 = 0.291$), Monohull sailors (P1 = 79.34 ± 1.21% vs. P2 = 74.79 ± 1.57%; $p = 0.029$) and Windsurfing sailors (P1 = 81.09 ± 1.36% vs. P2 = 76.32 ± 1.45%; $p = 0.023$). However, no differences were found in category ($F = 1.365$; $p = 0.253$; $\eta_p^2 = 0.048$) or performance·category ($F = 0.006$; $p = 0.937$; η_p^2 <0.001) (see Fig. 2).

Distribution of body muscle mass on the trunk, arm and leg segments are presented in Table III. Statistical differences were detected, with a higher level of muscle mass in P1 sailors compared to P2 sailors for the total sample in trunk ($F = 13.990$; $p = 0.001$; $\eta_p^2 = 0.341$), arms ($F = 9.363$; $p = 0.005$; $\eta_p^2 = 0.257$) and legs ($F = 6.844$; $p = 0.014$; $\eta_p^2 = 0.202$), with differences found in Windsurfing sailors (P1 vs P2) in these three body segments (trunk: $p = 0.003$; arms: $p = 0.008$; legs: $p = 0.028$). In the analysis of category, no differences were observed in trunk ($F = 1.203$; $p = 0.282$; $\eta_p^2 = 0.043$) or legs ($F = 0.063$; $p = 0.803$; $\eta_p^2 = 0.002$), and a higher muscle mass was identified in arms in Windsurfing sailors with respect to Monohull sailors ($F = 5.893$; $p = 0.022$; $\eta_p^2 = 0.179$), with differences between P1 Windsurfing and P1 Monohull ($p = 0.014$), but not between P2 Windsurfing and P2 Monohull ($p = 0.346$).

4. Discussion

The aim of the present study was to analyse possible differences in anthropometric characteristics of elite sailors between categories (Monohull and Windsurfing) and based on performance level. Regarding performance, it was observed that P2 sailors were

Table 2
Results of fat mass of different body segments of the sailors according to category and performance.

Variable	Category	Performance		
		50th percentile (P1)	100th percentile (P2)	Total
Fat mass trunk (%)	Monohull	4.44 ± 1.03 *	7.83 ± 3.58 *	5.71 ± 2.79
	Windsurfing	3.21 ± 1.42 *	6.81 ± 4.53 *	4.89 ± 3.64
	Total	3.89 ± 1.34 *	7.28 ± 3.99 *	5.32 ± 3.20
Fat mass arms (%)	Monohull	2.33 ± 0.20 *	2.75 ± 0.32 *	2.48 ± 0.32 λ
	Windsurfing	2.02 ± 0.36 *	2.45 ± 0.61 *	2.22 ± 0.52 λ
	Total	2.19 ± 0.32 *	2.59 ± 0.51 *	2.36 ± 0.45
Fat mass legs (%)	Monohull	3.50 ± 0.49	4.24 ± 0.66	3.78 ± 0.65
	Windsurfing	3.48 ± 0.78	4.12 ± 1.18	3.81 ± 1.02
	Total	3.49 ± 0.61 *	4.22 ± 0.94 *	3.80 ± 0.83

Data presented as M ± SD. Statistical differences fixed at $p < 0.05$.λ
* Statistical differences between sailors of different performance in the same category of sailing.
λ Statistical differences between sailors of different categories in the same performance of sailing.

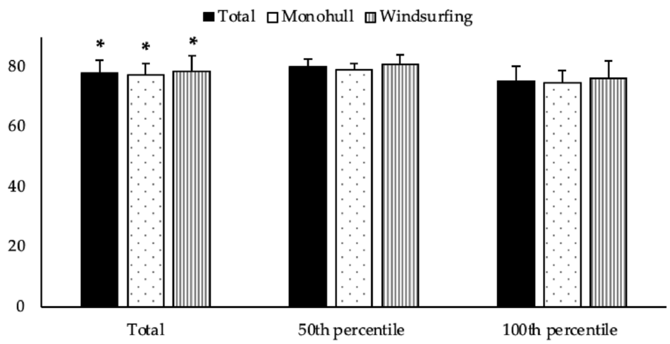

Fig. 2. Body muscle mass (expressed as percentage) of the sailors according to category and performance.
Data presented as M ± SD. Statistical differences fixed at $p < 0.05$. *: statistical differences between sailors of different performance in the same category of sailing.

taller and heavier than P1 sailors. Similarly, P1 sailors presented a lower BMI, total body fat mass and body fat mass in the trunk, arms, and legs than P2 sailors. In addition, P1 sailors showed a higher total body muscle mass, and body muscle mass in the trunk, arms and legs compared to P2 sailors. Regarding the categories, no differences were detected in height, weight, BMI, total body fat mass or total body muscle mass; however, greater arm fat mass was observed in Monohull sailors compared to Windsurfing sailors. Nevertheless, only in Windsurfing, differences were detected between P1 sailors and P2 sailors. Furthermore, greater arm muscle mass was identified in Windsurfing, although this difference was only detected between P1 sailors in Monohull vs Windsurfing. To the best of the authors' knowledge, this is the first study to evaluate the variables body weight, height, BMI, percentages of total fat mass, trunk fat mass, arm fat mass, leg fat mass, total muscle mass, trunk muscle mass, arm muscle mass and leg muscle mass in a real competition situation as a function of the performance of the sailors.

In the present study, to compare the performance level groups, it was observed that the sailors of the high-performance group had lower body weight in Monohull and Windsurfing categories. This result was observed when the comparisons were made in the total sample. Some studies have described the relationship between performance and body weight in Monohull sailors (Laser class), where these two variables presented a strong negative correlation.[6,9] Low body weight may reduce the hydrodynamic drag on the boat or board in the planning condition, allowing the sailor to achieve high speed in the most optimal conditions; this is due to the fact that a smaller area of the hull is in contact with the water, and thus the hull displaces less water from its path.[2]

Regarding the BMI, when comparing the total sample of sailors, it was observed that the high-level group showed low values of BMI. However, when comparing the sailors of the Monohull and Windsurfing groups separately and between the two categories, no differences were observed. Our results suggest that this variable is key to the performance of these groups of sailors. A study with sailors of the Laser and 470 class showed that those sailors with a greater BMI, within normal weight parameters, could facilitate the stability of the boat only in strong wind conditions.[21] However, sailing is a complex sport in which weather conditions are unstable and performance could be determined by the ability to understand and anticipate the weather conditions.[22] Thus, having a higher BMI could negatively affect performance when the winds are medium or light. This can be explained by the fact that the sailor would have a greater resistance, which could delay the advance or speed of the boat.

The results of the present study show that the most successful group of sailors of the total sample, the Monohull category, and the Windsurfing category, had lower percentages of total fat mass, trunk fat mass, arm fat mass, and leg fat mass compared to the less successful sailors. As in other sports, the excessive fat mass could be considered a disadvantage, as it decreases the efficiency of movement and, therefore, performance can be adversely affected.[23] In sailing, the mobility and range of motion of sailors could be affected by a worse ratio of lean-vs-fat body mass, worsening the capability of changing position during tacking.[24]

As was expected, regarding the percentage of total muscle mass in the total sample, Monohull category and Windsurfing category, it was observed that elite sailors have a greater percentage compared to the less successful sailors. Performance in the Windsurfing and Monohull categories is directly associated with the capacity of the sailor to overcome the external forces imposed by the board/boat and rig.[2,25] Since sailors need muscular strength to develop technical and tactical skills, this will determine the sailing performance.[26,27]

Furthermore, the results show that the elite Windsurfing sailors have greater percentage of arm muscle mass and leg muscle mass compared to low-level sailors. Muscular strength in upper and lower limbs is commonly considered an important characteristic for improved performance in boardsailing.[28] In the Windsurfing class, the main muscles are: trapezius, flexor carpi ulnaris, extensor carpi radialis, biceps brachii, gluteus maximus and tibialis anterior.[29] Therefore, and based on the obtained results, we can assume that this aspect is key in the difference of level performance of Windsurfing sailors.

Regarding the differences between categories, it was observed that the sailors of the Monohull category had a greater percentage of arm fat mass compared to the Windsurfing category. Similarly,

Table 3
Results of muscle mass of different body segments of the sailors according to category and performance.

Variable	Category	Performance		
		50th percentile (P1)	100th percentile (P2)	Total
Trunk muscle mass (%)	Monohull	27.54 ± 3.63	31.11 ± 3.31	28.88 ± 3.84
	Windsurfing	25.13 ± 2.94 *	30.81 ± 3.56 *	27.78 ± 4.29
	Total	26.47 ± 3.47 *	30.95 ± 3.31 *	28.35 ± 4.03
Arms muscle mass (%)	Monohull	3.89 ± 0.16 λ	3.71 ± 0.19	3.82 ± 0.19 λ
	Windsurfing	4.19 ± 0.26 *, λ	3.84 ± 0.33 *	4.03 ± 0.34λ
	Total	4.03 ± 0.25 *	3.78 ± 0.27 *	3.92 ± 0.29
Legs muscle mass (%)	Monohull	13.56 ± 0.81	12.94 ± 0.68	13.33 ± 0.80
	Windsurfing	13.85 ± 1.12 *	12.81 ± 0.74 *	13.36 ± 1.07
	Total	13.69 ± 0.94 *	12.87 ± 0.69 *	13.35 ± 0.92

Data presented as M ± SD. Statistical differences fixed at $p < 0.05$.λ
* Statistical differences between sailors of different performance in the same category of sailing.
λ Statistical differences between sailors of different categories in the same performance of sailing.

comparing the muscle mass between the categories, it was observed that higher-level Windsurfing sailors presented a higher arm muscle mass. Our results suggest that, in this study, the anthropometric characteristic of the upper limbs could be the variable that would determine sailor performance. Furthermore, it could determine the anthropometric differences between these two classes of sailors. Concerning the upper limbs in elite Windsurfing sailors, studies have shown that these athletes have high activation in the shoulder and arm muscles.[29] Moreover, upper body strength and endurance are very important for boardsailors to maintain control of the board and achieve good performance in regattas.[28] Therefore, it could be considered that the most suitable type of boat according to the characteristics of the sailor is determined by the anthropometric profile.[30] Thus, optimal anthropometric requirements differ among these boat classes. These findings could be useful to prepare specific training programmes accordingly.

In our study, we can consider some limitations. Firstly, the sample of the present study can be a limitation. Having a more representative sample would have allowed us to draw more precise conclusions, and a more balanced sampled in terms of age and sex would have allowed comparing boys and girls in each of the categroy group. Therefore, this limitation could condition the interpretation of the results of our study. Thus, the number of participants analysed consisted of only 42 sailors. However, this represents 37% of the total sailors who participated in this regatta. On the other hand, analysing the relationship between the speed of the boat and the anthropometric characteristics of the sailor could be a future line of research. In addition, the use of bioelectrical impedance is a limitation of the study. A multi-frequency stand-on hand to foot 8-electrode bioimpedance was used for the estimation of body composition parameters. These devices have previously been validated against dual-energy x-ray absorptiometry (DXA), showing high correlations between devices for fat free mass, fat mass, and percentage of body fat estimation. Furthermore, the mean difference between the equations derived from bioimpedance and DXA are small and not significant, suggesting the validity of bioimpedance as an alternative for the estimation of body composition parameters when DXA is not available.[31] Finally, no information was gathered about the metabolic responses during the regatta. Combined with the analysis of the physiological characteristics, it would give information about physiological demands during regatta. These results can be of great interest to coaches of sailors, since they can help them in the development and prescription of training programmes by coaches in preparing individual players for competition; unfortunately, it was not possible to include such data in our study. Moreover, future studies could be focused on the analysis of the physiological characteristics combined with metabolic responses during the regatta.

5. Conclusions

The results of our study show statistical differences between the two performance groups. In this way, the group with a better level of performance presented a lower BMI, total body fat mass and body fat mass in the trunk, arms, and legs. Similarly, this group showed a higher total body muscle mass and body muscle mass in the trunk, arms and legs compared to the low-performance group. In addition, the sailors of the low-performance group were taller and heavier. These findings could help to differentiate the anthropometric variables that determine sport performance in young elite sailors.

Regarding the analysed categories, the Windsurf sailors presented lower arm fat mass with statistical differences compared to the Monohull sailors. Furthermore, the Windsurf sailors showed differences between the two performance-level groups. Additionally, comparing the high-level performance groups in both categories, higher arm muscle mass was detected in the Windsurfing category. This finding could be used to differentiate the anthropometric variables in each category.

Author statement

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Authors' contributions

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Declaration of competing interest

The authors report no conflicts of interest.

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