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Strength Asymmetries in Young Elite Sailors: Windsurfing, Optimist, Laser and 420 Classes

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Abstract: Strength asymmetries in the upper and lower limbs may affect the body movements of the joints or limbs. Although asymmetries in the upper limbs have been studied in sailors, those in lower limbs have not been evaluated in this sport population. The aims of this study were: (i) to analyze lower limb asymmetries in young elite sailors in order to quantify the magnitude of asymmetry between limbs for variables that were established as reliable in a healthy population, and (ii) to evaluate the presence of differences between classes and sexes in inter-limb asymmetries in elite youth sailors. Sixty-eight young Spanish elite sailors (9–19 years of age) participated voluntarily in our study. Single-leg vertical countermovement jump (VCJ), single-leg horizontal countermovement jump and hand dynamometry tests were used to evaluate the strength of the upper and lower limbs. More than 50% of the sailors presented asymmetries in the lower limbs. The boys' group and Optimist class presented a greater percentage of strength asymmetry.

Keywords: symmetry; asymmetry; sport sailing; strength

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1. Introduction

Dinghy sailing is a sport in which the strength of the upper and lower limbs determines performance [1,2]. In the monohull type, such as the Optimist, Laser and 420 classes, performance is related to the ability of the sailor to keep the boat stable [3]. The sailor performs a specific technical gesture to stabilize the boat, which is called "hiking bench". In this action, the sailor places his/her feet in straps near the centerline of the boat and leans his/her body overboard in order to balance the moment of the resulting forces [1]. The quadriceps is one of the most important muscles involved in the hiking bench, and the muscular action is not constant isometric action, since small modifications are carried out by the sailor to adapt to the constant movements of the boat, which are produced by the action of the waves and wind [4,5]. Studies show that, in Olympic sailors of the Laser class, the maximum quadriceps strength is strongly related to successful performance [6]. With respect to upper limb strength, it has been shown that hand grip may be related to sailor performance in the Tornado [7] and Windsurfing [2] classes. Sailors use the strength of their finger and elbow flexor to control the direction and speed of the boat [8,9].

Sports practice causes asymmetrical development of bones and musculature of the dominant limb [10]; similarly, asymmetry in the upper limbs may also impact the asymmetry of the lower limbs and vice versa [11]. Mechanical and genetic factors will determine the degree of asymmetry. Sports training carried out during sports practice will produce a strain that may influence the morphological characteristics of both sides of the body [12], and such strain also depends on the particular discipline practiced [13,14]. Asymmetries in strength can be adversely affected by the body movements of the joints or limbs [15,16]. Therefore, identifying and assessing any asymmetry in athletes could be important for athletic performance and injury prevention.

In dinghy sailing, hiking bench is not always performed simultaneously with both legs, since the sailor uses each leg alternately to avoid fatigue [17]. Thus, this may not be a symmetrical task, as elite sailors produce asymmetrical forces in the lower limbs, and the action of the dominant leg is likely to be more recurrent, which could produce asymmetries between both legs. Therefore, this could result in chronic adaptations of asymmetry [18]. Regarding the upper limbs, studies have shown that elite sailors in the Windsurfing, Optimist and Laser classes have about 40% strength asymmetry in this part of the body [1].

To our knowledge, there are no studies in the literature focused on lower limb strength asymmetry in sport sailors, and little is known about sailors' asymmetry among the different dinghy classes. Therefore, the aims of this study were to investigate asymmetries in strength and to evaluate the presence of asymmetry differences between classes and sexes in young elite sailors.

2. Materials and Methods

2.1. Participants

Sixty-eight young Spanish elite sailors (26 girls and 42 boys) from the Windsurfing (n = 15, 11 girls and 4 boys), Optimist (n = 29, 4 girls and 25 boys), Laser (n = 18, 7 girls and 11 boys) and 420 (n = 6, 4 girls and 2 boys) classes, in the age range of 9–19 years, participated in this study.

2.2. Testing Procedures

All subjects, their parents and coaches were contacted by email and were invited to participate in the study. All sailors gave informed consent and were given information concerning the study.

Testing was performed in one session. Before testing, each subject´s age, height, mass, one leg length, hip height at 90° sailing experience, dominant hand and dominant leg were recorded. The subjects completed a standardized warm-up that consisted of 3 min of jogging, 10 reps of lunge walks with each leg, 10 vertical jumps with hands on hips, and 5 horizontal jumps (5 with both legs and 5 with one leg). After the warm-up, the subjects performed 3 practice trials for each of the jump assessments. The jump assessments consisted in a single-leg vertical countermovement jump (VCJ) and single-leg horizontal countermovement jump (HCJ) performed with the dominant and non-dominant leg. Leg dominance was defined as the leg the athlete preferred to use to kick a ball. During the test, the subjects were requested to keep their hands placed on their hips [19]. The first jump was always done with the right leg. After the jump assessments, a hand dynamometry (HD) test was performed.

2.3. Single-Leg Vertical Countermovement Jump (VCJ)

The My Jump 2® app was used to evaluate the single-leg vertical countermovement jump. This application requires the recording of the jump in slow motion for further analysis. The videos were captured with an iPhone® SE 2020 at 240 frames per second. Subsequently, the videos were downloaded and analyzed in the app of the iPhone® SE 2020. This app is valid and reliable for an iPhone® app [20]. The evaluator recorded always from the same position and at the same distance from the subjects (3 m), following the standard calibration of the device instructions. The app required the following data to be entered: mass, leg length and hip height.

2.4. Single-Leg Horizontal Countermovement Jump (HCJ)

For the HCJ, each participant began by standing on the designated testing leg with hands on the hips and the toe at the starting line. All subjects were instructed to jump as far forward as possible and land on one foot. The distance jumped was measured to the nearest 1 cm using a measuring tape measure and measuring the distance between the heel and the starting line [19].

2.5. Hand Dynamometry (HD)

Each subject held the dynamometer with one hand and exerted maximum strength for two seconds. Two trials were made with each hand, and the better of those two trials was recorded. After five seconds of rest, the subject repeated the test with the other hand [21]. A short warm-up was performed to familiarize with the device.

A manual dynamometer (Computational Bio-Systems, SL brand, produced by TAKEI), was used to quantify the manual compression force of the subjects (minimum unit of measure: 1 kg).

2.6. Symmetry Index (SI)

The SI is used to assess body asymmetry in athletes and it allows to compare the symmetry between the right and left side of the body and between the upper and lower limbs [22,23]. It is considered an important variable to assess asymmetries in athletes, since this allows understanding imbalances regarding the functional strength of the upper and lower body [24].

The following formula is used to quantify strength asymmetry:

$$SI = \frac{Xr - Xl}{\frac{1}{2}(Xr + Xl)} \cdot 100\%$$

where *Xr* is the value for the right side and *Xl* for the left side. A value of zero in SI means that the subject do not show asymmetries. A positive value of *SI* indicates that *Xr* is greater than *Xl*, and a negative value indicates that *Xr* is lower than *Xl* [25]. The subject showed asymmetry when SI is greater than 10 percent [26].

2.7. Functional Asymmetry of Compression Force (FACF)

The following formula is used to calculate the functional asymmetry of compression force [27]:

$$Kas = \frac{Er - El}{Er + El}$$

where *Kas* is the asymmetry coefficient (AC), *Er* is the right hand´s compression force, and *El* is the left hand´s compression force. A negative value of *Kas* indicates the dominance of the left hand and a positive value indicates the dominance of the right hand.

2.8. Statistical Analyses

Results are presented as means and standard deviations. The level of significance was set at $p < 0.05$. For the statistical analyses, the statistical package SPSS v20.0 (SPSS Lead Technologies Inc., Chicago, IL, USA) was used. The data were subjected to a descriptive analysis and inferences, and their normality was assessed using the Kolmogorov-Smirnov test. Counts (frequencies) and proportions were calculated for all the data. The analysis of variance (ANOVA) was used to analyze possible differences in the mean values of the variables among Windsurfing, Optimist, Laser and 420 class groups. A Bonferroni correction was performed when statistically significant differences were detected. The analysis to compare the data based on sex was carried out for the total sample, although the boat classes were excluded from this analysis.

Table 1 shows the results of the descriptive analysis of the total sample and by sex. The analysis of the mean values did not show differences in the variables according to sex.

Table 2 shows the descriptive analysis for each of the groups of sailors. It is observed that the sailors of the Optimist class had lower age than those in the Laser ($p < 0.01$), Windsurfing ($p < 0.01$) and 420 ($p < 0.01$) groups, lower height than those in the Laser group ($p < 0.01$), and lower experience than those in the 420 group ($p < 0.01$). The Laser group had greater mass than the Optimist ($p < 0.01$), Windsurfing ($p < 0.01$) and 420 ($p < 0.05$) groups. The strength of the upper and lower limbs of the athletes in the Laser group was greater than that of those in the Optimist ($p < 0.01$) and Windsurfing ($p < 0.01$) groups. The results of the power countermovement jump test show that the Laser group had greater higher power than the Optimist ($p < 0.01$) and Windsurfing ($p < 0.05$) groups in the right leg, and greater power than the Optimist ($p < 0.01$) group in the left leg, since this difference was not significant with respect to the 420 class group. Regarding the dominant side in the upper and lower limbs (strength and power), the Laser group obtained higher results compared to the Optimist and Windsurfing groups, with a p value below 0.01 in all cases (Table 2). With regard to the non-dominant side, the values of the sailors of the Laser group were also greater than those of the Optimist ($p < 0.01$) and Windsurfing ($p < 0.01$) groups, since the differences with the Windsurfing group were not significant in the power of the lower limbs (CJM power). No differences were found when comparing the symmetry indices and the values of functional asymmetry of compression force between the four class groups.

No significant differences were observed when comparing the dominant side with the non-dominant side in each of the analyzed groups (Table 3).

Table 4 shows the percentage of sailors who had positive or negative asymmetry according to the obtained SI and Kas values. When comparing the total sample of sailors (i.e., the four classes together) by sex, it was observed that the group of girls had a greater percentage of asymmetries in hand dynamometry than the boys. When analyzing the values of AC in this variable for these groups, it was verified that the right side prevailed as dominant for both groups. Regarding VCJ, the boys showed greater values in asymmetry (59.8% versus 41.8%), and the same situation occurred when HCJ was analyzed (40.6% versus 34.5%). The analysis between the different classes reflects that more than half of the sailors of the Optimist (61.6%) and Laser (55.8%) groups had asymmetry in VCJ, and that the right hand was the dominant one in the four groups. The values in HCJ indicate that the Optimist class group had the highest percentage of sailors with asymmetry (51.5%), while in the 420 class, there were no sailors with asymmetry.

Table 1. Mean ± SD of the variables analyzed in all sailors, boys and girls.

	All (*n* = 68)	**Girls** (*n* = 26)	**Boys** (*n* = 42)	*d*
Age (years)	13.9 ± 2.1 (9–19)	14.3 ± 1.8 (9–17)	13.6 ± 2.3 (9–19)	0.02
Height (cm)	159. 9 ± 11.5 (134–183)	159.2 ± 5.7 (146–170)	160.3 ± 13.9 (134–183)	0.0
Mass (kg)	53.7 ± 14.8 (28.8–112)	52.4 ± 11.2 (35.5–89.7)	54.5 ± 16.2 (28.8–112)	0.0
Experience (years)	5.6 ± 2.5 (1–11)	5.8 ± 2.3 (2–10)	5,5 ± 2,6 (1–11)	0.0
Right HD (kg)	30.6 ± 9.8 (13.4–59)	28.4 ± 5.1 (14.6–36)	32.1 ± 11.6 (13.4–59)	0.03
Left HD (kg)	29.5 ± 9.5 (12.7–58)	27.4 ± 5.7 (15.5–37.9)	30.8 ± 11.1 (12.7–58)	0.03
Do HD (kg)	30.6 ± 9.8 (13.4–59)	28.3 ± 5.5 (14.6–37.5)	32.1 ± 11.5 (13.4–59)	0.03
Nod HD (kg)	29.5 ± 9.5 (12.7–58)	27.5 ± 5.4 (15.5–37.9)	30.8 ± 11.3 (12.7–58)	0.02
HD SI (%)	3.6 ± 11.1 (–21.9–37.5)	3.8 ± 13.2 (–21.9–37.5)	3.6 ± 9.8 (–16.8–28.9)	0.0
AC (kg)	0.01 ± 0.05 (–11–19)	0.01 ± 0.06 (–0.1–0.1)	0.01 ± 0.04 (–0.08–0.1)	0.0
Right S_VCJ (N)	658.9 ± 169.6 (336.9–1253)	634.3 ± 99.4 (434.6–874.5)	674.2 ± 200.8 (336.9–1252.9	0.01
Left S_VCJ (N)	653.6 ± 168.2 (338.7–1131.5)	620.6 ± 107.1 (401.9–895.1)	674.1 ± 195.2 (338.7–1131.5)	0.02
Do S_VCJ (N)	658.5 ± 171.9 (336.9–1252.9)	631.9 ± 111.2 (401.9–895.1)	675 ± 200 (336.9–1252.9)	0.01
Nod S_VCJ(N)	654.1 ± 165.9 (338.7–1131.5)	622.9 ± 95.2 (434.6–874–5)	673.2 ± 196.1 (338.7–1131.5)	0.02
Right P_VCJ (W)	465.1 ± 162.9	435.9 ± 100.6 (269.2–659.9)	483.1 ± 190.6 (186.5–890.9)	0.02
Left P_VCJ (W)	452.4 ± 172.1 (189.7–914.6)	409.2 ± 105.1 (–27.5–39.1)	479.1 ± 199.2 (189.75–914.6)	0.03
Do P_VCJ (W)	466.3 ± 164.4 (193–890.9)	436 ± 113.6 (200.8–659.9)	485 ± 188.1 (193–890.9)	0.02
Nod P_VCJ (W)	451.1 ± 170.4 (186.5–914.6)	409.1 ± 90.8 (269.9–601.1)	477.1 ± 201.5 (186.5–914.6)	0.03
P_VCJ SI (%)	3.6 ± 19.7 (–42.2–82.3)	6.9 ± 15.6 (–27.5–39.1)	1.6 ± 21.8 (–42.2–82.3)	0.01
Right HCJ (cm)	124.9 ± 26.5 (71.6–183.11)	113.1 ± 18.1 (71.6–140)	132.2 ± 28.5 (78.4–183.1) *	0.12
Left HCJ (cm)	125.7 ± 27.1 (55–183)	115.8 ± 16.1 (89–153.8)	131.8 ± 30.6 (55–183) *	0.08
Do HCJ (cm)	126.6 ± 25.4 (71.6–183.1)	115.8 ± 16.8 (71.6–140)	133.3 ± 27.62 (78.4–183.1) **	0.11
Nod HCJ (cm)	124.6 ± 25.4 (71.6–183.1)	113.2 ± 17.5 (81–153.8)	130.7 ± 31.3 (55–183) **	0.09
HCJ SI (%)	–0.5 ± 16.8 (–51.1–66.7)	–2.6 ± 15.7 (–51.1–26.8)	0.8 ± 17.5 (–48.1–66.7)	0.01

Note: (minimum–maximum); HD: Hand dynamometry; SI: Symmetry Index; AC: Asymmetry coefficient; S_VCJ: Strength single-leg vertical countermovement jump test; P_VCJ: Power single-leg vertical countermovement jump test; P_VCJ SI: Power single-leg vertical countermovement jump Symmetry Index; HCJ: Single-leg horizontal countermovement jump; HCJ SI: Single-leg horizontal countermovement jump Symmetry Index; Do: Dominant side; Nod: Non-dominant side; d = effect size; * = $p > 0.05$; ** = $p > 0.01$.

Table 2. Mean ± SD of the variables analyzed in the Windsurfing, Optimist, Laser and 420 class groups.

	Windsurfing (n = 15)	Optimist (n = 29)	Laser (n = 18)	420 (n = 6)	d
Age (years)	14.1 ± 1.2 (12–16)	12.2 ± 1.5 (9–14) [A]	15.9 ± 1.5 (13–19)	15.5 ± 1.3 (14–17)	0.53
Height (cm)	160.3 ± 7.8 (146–175)	153.4 ± 11.8 (134–173)	169.1 ± 7.4 (159–183) [E]	163 ± 8.2 (153–173)	0.31
Mass (kg)	50.9 ± 7.8 (36.4–63.5)	47.1 ± 12.1 (28.8–79.2)	67.4 ± 15.5 (47–112) [C]	51.4 ± 6.5 (42.7–60.6)	0.34
Experience (years)	5,9 ± 2,9 (2–11)	4,5 ± 2 (1–9) [B]	6,3 ± 2,1 (3–10)	8,1 ± 2,6 (4–11)	0.51
Right HD (kg)	30.6 ± 10.2 (14.6–56.3)	25.8 ± 7.7 (13.4–45.4)	37.5 ± 9.5 (21–59) [E]	32.9 ± 6.7 (26.6–44.6)	0.24
Left HD (kg)	27.9 ± 8.5 (18.2–48.8)	24.8 ± 7.5 (12.7–41)	37.4 ± 9.2 (20–58) [D]	32.5 ± 6.3 (24.5–40.4)	0.3
Do HD (kg)	30.5 ± 10.3 (14.6–56.3)	25.7 ± 7.6 (13.4–45.4)	37.9 ± 9.2 (20–59) [E]	32.9 ± 6.7 (26.6–44.6)	0.25
Nod HD (kg)	28 ± 8.4 (18.2–48.8)	24.9 ± 7.7 (12.7–41)	37.1 ± 9.5 (21–58) [D]	32.5 ± 6.3 (24.5–40.4)	0.28
HD SI (%)	8.1 ± 13.5 (−21.9–37.5)	4.1 ± 10.4 (−14.37–28.9)	0.1 ± 10.5 (−18.3–15.5)	1.1 ± 7.5 (−7.9–9.8)	0.06
AC (kg)	0.04 ± 0.06 (−11–0.1)	0.02 ± 0.05 (−0.07–0.1)	0.0008 ± 0.05 (−0.09–0.08)	0.005 ± 0.03 (−0.04–0.05)	0.06
Right S_VCJ (N)	638.5 ± 96.5 (497.1–810.5)	568.7 ± 137.6 (336.9–870.1)	819.7 ± 168 (569.8–1252.9) [D]	663.5 ± 124.9 (523.9–864.2)	0.03
Left S_VCJ (N)	627.6 ± 108.8 (445.1–806.3)	565.2 ± 142.7 (338.7–897.9)	813.7 ± 146.6 (569.8–1131.5) [D]	664.8 ± 138.9 (527.1–881.9)	0.36
Do S_VCJ (N)	631.5 ± 107.5 (445.1–810.5)	568.8 ± 138.2 (336.9–870.1)	823.7 ± 166.1 (569.8–1252.9) [D]	663.5 ± 124.9 (523.9–864.2)	0.37
Nod S_VCJ(N)	634.6 ± 98.2 (498.4–806.3)	565.1 ± 142.1 (338.7–897.9)	809.7 ± 148.4 (569.8–1131.5) [D]	664.8 ± 138.9 (527.1–881.9)	0.36
Right P_VCJ (W)	454.3 ± 118.1 (269.2–653.5)	375.1 ± 115.9 (186.5–659.9)	595.2 ± 170.6 (326.1–890.9) [D]	535.9 ± 167.4 (358.1–794.8)	0.32
Left P_VCJ (W)	438.1 ± 126.4 (269.9–646.2)	366.3 ± 122.6 (189.7–601.1)	575.8 ± 188.1 (277.5–914.6) [D]	534.2 ± 201.6 (365.7–837.2)	0.26
Do P_VCJ (W)	447.6 ± 124.9 (269.2–653.3)	375.7 ± 116.1 (193–659.9)	604.5 ± 164.5 (326.1–890.9) [D]	535.9 ± 167.4 (358.1–794.8)	0.33
Nod P_VCJ (W)	444.8 ± 120.2 (269.9–646.2)	365.6 ± 122.3 (186.5–601.1)	566.5 ± 192.1 (277.5–914.6) [E]	534.2 ± 201.6 (365.7–837.2)	0.25
P_CMJ SI (%)	4.3 ± 14.9 (−27.5–39.1)	3.1 ± 19.2 (−42.2–48.8)	4.6 ± 26.6 (−34.9–82.3)	1.8 ± 9.8 (−8.9–17.3)	0.0
Right HCJ (cm)	125.3 ± 22.2 (97.6–165.4)	117.9 ± 28.8 (71.6–172)	132.3 ± 22.3 (85–182)	135.7 ± 32.9 ((101.7–183.1)	0.06
Left HCJ (cm)	125.2 ± 22.4 (89.5–165)	124.4 ± 26.4 (64–175)	126.2 ± 32.2 (55–183)	131.8 ± 29.9 (95.7–170.6)	0.0
Do HCJ (cm)	126.2 ± 21.7 (97.6–165.4)	121.1 ± 27.9 (71.6–172)	132.8 ± 20.7 (100–182)	135.7 ± 32.9 (101.7–183.1)	0.04
Nod HCJ (cm)	124.3 ± 22.9 (89.5–165)	121.2 ± 27.7 (64–175)	125.6 ± 33.2 (55–183)	131.8 ± 29.9 (95.7–170.6)	0.01
HCJ SI (%)	0.1 ± 9.5 (−12.3–26.8)	−5.9 ± 18.5 (−51.1–32.6)	6.6 ± 19 (−18.7–66.6)	2.6 ± 4.2 (−3.6–7)	0.09

Note: $p < 0.05$; (minimum–maximum); HD: Hand dynamometry; SI: Symmetry Index; AC: Asymmetry coefficient; S_VCJ: Strength single-leg vertical countermovement jump test; P_VCJ: Power single-leg vertical countermovement jump test; P_VCJ SI: Power single-leg vertical countermovement jump Symmetry Index; HCJ: Single-leg horizontal countermovement jump; HCJ SI: Single-leg horizontal countermovement jump Symmetry Index; Do: Dominant side; Nod: Non-dominant side.; [A]: Statistically significant difference among Optimist and Laser, Windsurfing and 420 classes; [B]: Statistically significant difference between Optimist and 420 classes. [C]: Statistically significant difference among Laser and Optimist, Windsurfing and 420 classes; [D]: Statistically significant difference between Optimist and Windsurfing classes; [E]: Statistically significant difference between Laser and Optimist classes; d = effect size.

Table 3. Comparison between the dominant and non-dominant side for hand dynamometry (HD), single-leg power vertical countermovement jump (CVJ) and single-leg horizontal countermovement jump (CHJ) (mean ± SD).

	Do HD (kg)	Nod HD (kg)	Do P_VCJ (W)	Nod P_VCJ (W)	Do HCJ (cm)	Nod HCJ (cm)
All (n = 68)	30.6 ± 9.8 (13.4–59)	29.5 ± 9.5 (12.7–58)	658.5 ± 171.9 (336.9–1252.9)	654.1 ± 165.9 (338.7–1131.5)	126.6 ± 25.4 (71.6–183.1)	124.6 ± 25.4 (71.6–183.1)
Girls (n = 26)	28.3 ± 5.5 (14.6–37.5)	27.5 ± 5.4 (15.5–37.9)	436 ± 113.6 (200.8–659.9)	409.1 ± 90.8 (269.9–601.1)	115.8 ± 16.8 (71.6–140)	113.2 ± 17.5 (81–153.8)
Boys (n = 42)	32.1 ± 11.5 (13.4–59)	30.8 ± 11.3 (12.7–58)	485 ± 188.1 (193–890.9)	477.1 ± 201.5 (186.5–914.6)	133.3 ± 27.62 (78.4–183.1)	130.7 ± 31.3 (55–183)
Windsurfing (n = 15)	30.5 ± 10.3 (14.6–56.3)	28 ± 8.4 (18.2–48.8)	447.6 ± 124.9 (269.2–653.3)	444.8 ± 120.2 (269.9–646.2)	126.2 ± 21.7 (97.6–165.4)	124.3 ± 22.9 (89.5–165)
Optimist (n = 29)	25.7 ± 7.6 (13.4–45.4)	24.9 ± 7.7 (12.7–41)	375.7 ± 116.1 (193–659.9)	375.7 ± 116.1 (193–659.9)	121.1 ± 27.9 (71.6–172)	121.2 ± 27.7 (64–175)
Laser (n = 18)	37.9 ± 9.2 (20–59)	37.1 ± 9.5 (21–58)	604.5 ± 164.5 (326.1–890.9)	566.5 ± 192.1 (277.5–914.6)	132.8 ± 20.7 (100–182)	125.6 ± 33.2 (55–183)
420 (n = 6)	32.9 ± 6.7 (26.6–44.6)	32.5 ± 6.3 (24.5–40.4)	535.9 ± 167.4 (358.1–794.8)	534.2 ± 201.6 (365.7–837.2)	135.7 ± 32.9 (101.7–183.1)	131.8 ± 29.9 (95.7–170.6)

Note: (minimum–maximum); Do HD: Dominant hand dynamometry; Nod HD: Non-dominant hand dynamometry; Do P_VCJ: Dominant single-leg power vertical countermovement j; Nod P_VCJ: Non-dominant single-leg power vertical countermovement jump; Do HCJ: Dominant single-leg horizontal countermovement jump; Nod HCJ: Non-dominant single-leg horizontal countermovement jump.

Table 4. Percentages of sailors presenting asymmetry in the sample by gender and class according to the SI and AC values.

	All (n = 68)	Girls (n = 26)	Boys (n = 42)	Windsurf (n = 15)	Optimist (n = 29)	Laser (n = 18)	420 (n = 6)
Positive hand dynamometry SI	27%	30.4%	26.4%	40.2%	34%	22.4%	0%
Negative hand dynamometry SI	11.8%	11.5%	11.9%	6.7%	10.3%	22.2%	0%
Total hand dynamometry SI	38.8%	41.9%	38.3%	46.9%	44.3%	44.6%	0%
Positive AC	69.1%	65.4%	71.4%	80.4%	65.5%	66.7%	66.7%
Negative AC	30.9%	34.6%	28.6%	20%	34.5%	33.3%	33.3%
Positive VCJ SI	33%	34.2%	31.2%	33.5%	34%	33.6%	16.7%
Negative VCJ SI	20.6%	7.6%	28.6%	13.3%	27.6%	22.2%	0%
Total VCJ SI	53.6%	41.8%	59.8%	46.8%	61.6%	55.8%	16.7%
Positive HCJ SI	18%	11.4%	21.6%	6.7%	17%	33.6%	0%
Negative HCJ SI	20.6%	23.1%	19%	13.3%	34.5%	11.1%	0%
Total HCJ SI	38.6%	34.5%	40.6%	19.9%	51.5%	44.7%	0%

Note: SI: Symmetry index; AC: Asymmetry coefficient; VCJ: Single-leg power vertical countermovement jump; HCJ: Single-leg horizontal countermovement jump.

3. Discussion

This study was focused on the analysis of strength asymmetry of the upper and lower limbs in elite sailors. To our knowledge, this is the first study to evaluate strength asymmetry of the lower limbs in sailors in the Windsurfing, Optimist, Laser and 420 classes.

The strength results showed no differences between boys and girls, and the same situation occurred when comparing the age of the sailors. These results are similar to those obtained in another study, in which strength was evaluated by hand dynamometry in 33 sailors of the Windsurfing, Optimist and Laser classes [28]. These results might be unexpected, since, between the ages of 10 and 12, boys show improvements in strength compared to girls, mainly due to the fact that musculoskeletal structures in boys have a greater development in this age range [29].

Regarding the differences among classes, it was observed that the Laser class had greater mass compared to those of the Windsurfing, Optimist and 420 classes. Some studies have shown that elite sailors have greater mass, which benefits the sailor in the hiking bench technique [1,5]. This is probably related to the fact that Laser class sailors need high values in this parameter in order to control their boat movement. It could be considered that the anthropometric profile determines the type of boat that is most suitable according to the characteristics of the sailor, thus optimal anthropometric requirements differ among boat classes.

Regarding strength, the results show that the Laser class had a higher average value in HD and VCJ, for both the left and right hand and for the dominant and non-dominant side in the upper and lower limbs. When our results were compared with those of other studies, it was observed that the Optimist sailors had much lower HD values (31.4 ± 4 versus 25.7 ± 7.6 kg), which were also lower in the Laser class (55.6 ± 3.6 versus 37.9 ± 9.2 kg) [30]. The sample of the mentioned study consisted of seven elite sailors from the Optimist class and nine from the Laser class, with ages between 10 and 18 years. However, such study provides results from non-elite sailors, and those results were similar in the Optimist class (25.5 ± 8.1 versus 25.7 ± 7.6 kg) and lower in the Laser class (46.9 ± 10.6 versus 37.9 ± 9.2 kg). Therefore, it is possible to state that our Optimist and Laser class sailors have a low level of strength in the upper limbs, which was also observed when comparing with Windsurfing (46.9 ± 10.6 versus 30.5 ± 10.3 kg) and 420 classes (46.9 ± 10.6 versus 32.9 ± 6.7). The assessment of the results obtained in the VCJ test showed that the strength and power obtained by the sailors of the Laser class was greater than those of the Optimist and Windsurfing classes. The values were higher in the results obtained in the right and left leg, as well as in the dominant and non-dominant leg. The lower strength and power of the Optimist sailors in the lower limbs could be due to the fact that the sailors of this group were younger than those of the Laser group, thus the older the athlete the greater his/her strength [29]. ANCOVA comparisons were performed controlling for age to compare data among the different classes (results not shown). This analysis showed significant differences only in the comparisons of the following variables: dominant HD, non-dominant HD, dominant strength VCJ, non-dominant strength VCJ, dominant power VCJ and non-dominant power VCJ. Therefore, age is a variable that affects the interpretation of these results. The Windsurfing class performs the hiking bench in a different way than the Laser class, since, in the Laser class, this technical gesture requires a greater involvement of the knee extensor muscles [31]. Therefore, these athletes will have a better adaptation to the strength and resistance of these muscles.

No differences were found when comparing the average values of HD, VCJ and HCJ between the dominant and non-dominant sides, neither for the total sample nor by sex or class. Similarly, no lateral differences were found between sexes in the strength of the upper and lower limbs of the dominant and non-dominant sides, which is in line with other studies conducted with elite sailors [28]. Although our study did not show differences in bilateral asymmetry, previous studies have found that asymmetry is more notable during adolescence and increases with age [32].

Of the entire sample, 88.2% and 85.3% of the sailors were right-handed for the upper and lower limbs, respectively. In the upper limbs, it is usually reported that the dominant side is the right side, and it is estimated that the frequency of the left side being dominant is 10–13% [14]. With respect to the different classes, 93.3%, 89.7%, 77.8% and 100% of the sailors were right-handed in the Windsurfing, Optimist, Laser and 420 classes, respectively, for the upper limbs. For the lower limbs, the percentages of sailors with dominant right side in the Windsurfing, Optimist, Laser and 420 classes were 86.7%, 79.3%, 88.9% and 100%, respectively.

Our results show that lower limb asymmetries are greater in boys than in girls, and, in each of the different classes, the percentage of sailors who had asymmetries was higher than 45%, reaching 61.6% in some cases. These results indicate that there were muscular imbalances in the lower limbs of our sailors. Numerous studies have shown that imbalances in muscle strength not only affect performance but could also increase the risk of injury [33,34]. Therefore, through this type of analysis, it is possible to easily identify asymmetries in the lower limbs of sailors. The current findings regarding asymmetry may be used by coaches and sailors to determine the strength asymmetry characteristics in the analyzed classes and prepare specific training programs accordingly.

Our study is not exempt from limitations. Firstly, regarding the number of participants analyzed, the groups did not have the same number of subjects and the sample size was somewhat small. Secondly, no control group was included. A control group could allow determining how the inter-limb force variability is affected in a similar population of non-sailor athletes who practice a more "symmetric" sport activity.

4. Conclusions

There were no significant differences in the levels of strength in the upper and lower limbs between males and females. The sailors of the Laser class had higher levels of strength in the upper and lower limbs. There were no differences in upper or lower limb strength between the dominant and non-dominant sides. The group of boys showed a higher percentage of sailors with asymmetry in the lower limbs. The highest level of lower limb strength asymmetry was obtained by the Optimist class.

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