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Evaluation of the Hand Grip and Sheet Rope Pulling Strength in Laser Sailing Athletes by Using Hiking Bench

Sevgi Tuncel[1], İrfan Gülmez[1], Muhammed Yusuf Kahraman[2], Fatih Sani[1], Nusret Ramazanoğlu[1]

[1]Department of Coaches Education, Marmara University, Faculty of Sports Sciences, İstanbul, Türkiye
[2]Department of Recreation, Haliç University, Faculty of Sports Sciences, İstanbul, Türkiye

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Abstract

This study aimed to investigate hand grip and rope-pulling strength and endurance in laser-class sailors. Seventeen laser class sailors, 15 males and two females participated in this study voluntarily. Hand grip and sheet rope-pulling tests were performed on the hiking bench. To determine the hand grip and the sheet rope-pulling strength, the loadcell and Strength Sensor Platform software were used. No significant correlation was observed between the hand grip and sheet rope-pulling strength ($p > .05$). A positive correlation was observed between the strengths of two hands in hand grip and sheet rope pulling ($p < .01$). According to endurance levels, the main effect of Force × Side interaction was significant ($p = .038$). For post hoc tests, sheet rope-pulling endurance was higher than the hand grip and the left was higher than the right hand grip. In conclusion, a significant correlation was observed between right and left hand grip strength. Anthropometric parameters, particularly body mass index, have a significant relationship with hand grip strength, probably due to increased muscle mass. Furthermore, significant differences in endurance levels were observed in hand grip and rope-pulling, as well as between the right and left hands. These findings highlight the importance of integrating hand grip endurance activities into training to reduce asymmetric endurance levels.

Keywords: Hand grip, hiking bench, laser-class sailors, sheet rope pulling, strength and endurance

Lazer Sınıfı Yelken Sporcularında El Kavrama ve İskota Halatı Çekme Kuvvetinin Değerlendirilmesi

Öz

Bu çalışmanın amacı lazer sınıfı yelkencilerde el kavrama ve halat çekme kuvveti ve dayanıklılığını araştırmaktır. Çalışmaya 15 erkek ve 2 kadın olmak üzere 17 laser sınıfı yelkenci gönüllü olarak katılmıştır. El kavrama ve çarşaf ipi çekme testleri hiking bench üzerinde gerçekleştirilmiştir. El kavrama ve iskota halatı çekme kuvvetini belirlemek için loadcell ve Strength Sensor Platform yazılımı kullanılmıştır. El kavrama ve çarşaf ipi çekme kuvveti arasında anlamlı bir korelasyon gözlenmemiştir ($p > .05$). İki elin el kavrama ve iskota halatı çekme kuvvetleri arasında pozitif bir korelasyon gözlenmiştir ($p < .01$). Dayanıklılık seviyelerine göre Kuvvet*Taraf etkileşiminin ana etkisi anlamlı bulunmuştur ($p = .038$). Post hoc testlerinde, iskota halatı çekme dayanıklılığı el tutuşundan ve sol el tutuşu sağ el tutuşundan daha yüksek bulunmuştur. Sonuç olarak, sağ ve sol el kavrama kuvveti arasında anlamlı bir korelasyon gözlenmiştir. Antropometrik parametreler, özellikle de vücut kitle indeksi, muhtemelen artan kas kitlesine bağlı olarak el kavrama kuvveti ile anlamlı bir korelasyon göstermektedir. Ayrıca, el kavrama ve halat çekmede ve sağ ve sol eller arasında dayanıklılık düzeylerinde önemli farklılıklar gözlenmiştir. Bu bulgular, asimetrik dayanıklılık seviyelerini azaltmak için el kavrama dayanıklılığı aktivitelerinin antrenmana entegre edilmesinin önemini vurgulamaktadır.

Anahtar Kelimeler: El kavrama, iskota halatı çekme, lazer sınıfı yelkenciler, kuvvet ve dayanıklılık, hiking bench

Introduction

Sailing is a complex aquatic sport that requires a series of positional adjustments through intense grip and pull to move the boat by utilizing the energy of the wind (Pan et al., 2022). The Laser boat used in the present study is the most common and largest Olympic sailing class. The Laser class is the second most favored among young sailors following the Optimist. It is widely practiced in over 85 countries and by 160,000 athletes or more. Sailors can use 4.7, 5.76, and 7.06 m^2 sails, depending on their age and weight.

Laser-class sailing involves maneuvering the boat by leaning over the side (hiking) and managing the sails by pulling the sheet ropes (Callewaert et al., 2015). Especially, the strength and coordination between body parts during these maneuvers are important for performance in sailing (Bojsen-Møller et al., 2015). Hand grip strength influences performance, specifically in sports that rely on hand functions, such as sailing (Caraballo et al., 2021; Cronin et al., 2017). The gripping, pulling, and releasing of the sheet rope actions are generated by actively using the hand during sailing. It has been revealed that hand grip strength was related to sailor performance in Tornado

Corresponding Author: İrfan Gülmez
E-mail: irfan.gulmez@marmara.edu.tr

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and Windsurfing classes (Barrionuevo Vallejo et al., 2007; Vogiatzis et al., 2002). However, previous studies employed a hand dynamometer to assess hand grip strength during a standardized gripping position, without simulating a body position similar to hiking which is a technique used by sailors to stabilize the boat (Caraballo et al., 2021; Cunningham, 2004; Philippe et al., 2021).

The pulling strength is generated by the combined activation of the extensor muscles in the knee, trunk, and shoulder, thus maintaining the hiking position to balance the hull and optimize speed according to the environmental conditions (Bojsen-Møller et al., 2015; Sun & Pan, 2023). It has been shown that hiking performance has a moderate to strong positive correlation with the strength of knee and trunk extensors (Aagaard et al., 1998; Tan et al., 2006). Additionally, sustainable performance is a result of the strength and endurance of the shoulder extensors and elbow flexors (Bojsen-Møller et al., 2015; Philippe et al., 2021). Previous research has found that grinding (the cyclical action of catamaran sailors using upper limbs) performance is strongly correlated with maximum strength in bench press and bench pull (Pearson et al., 2009). Despite the strong correlation between hiking performance and extensor muscle strength, to the best of our knowledge, no study has evaluated hiking simulated pulling strength or endurance in elite Laser class sailors. The main purpose of this study was to investigate the strength and endurance of hand grip and sheet rope pulling (SRP) in laser-class sailors. An additional aim was to assess possible differences and relationships between the right and left hands. It was hypothesized that higher hand grip strength would provide higher SRP and a bilateral positive relationship would be observed in hand and sheet rope strength.

Methods

Participants

Seventeen laser class sailors, 15 males, and 2 females (age: 17.65± 1.62 years, height; 176 ± 5.59 cm, body weight; 76.5 ± 6.45 kg, body mass index; 23.80 ± 1.76 kg/m^2) participated in this study voluntarily. All the data are shown as left or right regardless of hand dominance, since 88.2% (15) of the sailors participating in our study were right-handed. The participants were healthy sailors with at least four years of experience in sailing. The sailors were informed about the purpose of the study and the test procedure and were asked to sign an informed consent form. In addition, the written consent of the parents and coaches was obtained for the children. The study protocol followed the Declaration of Helsinki (1964) guidelines and was approved by the Ethics Committee of Marmara University, Faculty of Medicine (Approval no: 09.2021.1236, Date: 23.12.2021).

Instrumentation

A load cell system (Load Cell Model DYLY-107) was used to measure hand grip and pull strength. The system converted the exerted force into an electrical signal. The software utilized for recording the force signal (Strength Sensor Platform V1.0) was custom-developed to display data obtained from the load cell. Hand grip strength was assessed using a force-measurement system integrated into a single-column load cell, which allows grasping and squeezing with the fingers (Figure 1). The SRP strength and endurance were measured by using an S-type load cell (Figure 2). Before the test, the hand grip and SRP measurement sensors were calibrated with 1 kg weight. Sheet rope pulling strength and endurance tests were performed on the hiking bench training equipment, which is a land-based ergometer, by creating a laser sailing boat simulation environment (Figure 3).

Figure 1.
Hand Grip Strength Device.

While obtaining the data during the measurement, the changes in position on the hiking bench training equipment were recorded, excluding the wind resistance in the simulator.

Test Procedure

Prior to testing, the sailors completed a self-determined warm-up and were given time to familiarize the tests. All tests were conducted

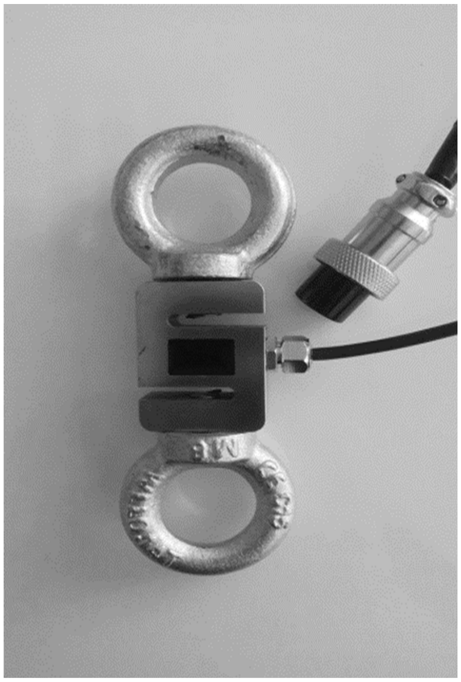

Figure 2.
S-Type Load Cell.

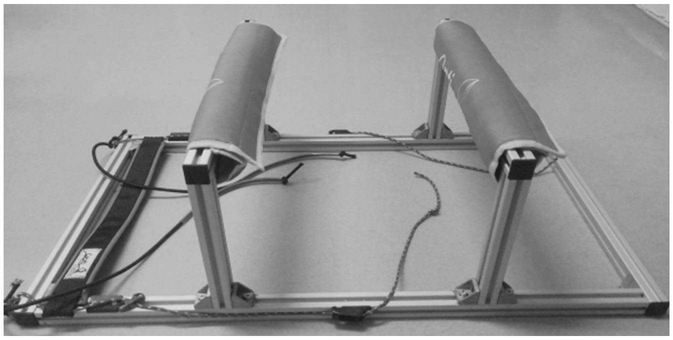

Figure 3.
Hiking Bench.

in three parts. First, maximal hand grip strength in the sitting position (HG), second, maximal SRP force with maximal hand grip on the hiking bench (HGHB), and third, endurance tests during SRP on the hiking bench were conducted (Figure 4 & 5). Three minutes were allowed to rest and recover between each of the parts.

In the first part, maximal hand grip strength was determined using a force measurement sensor. The sailors were asked to apply the maximum force they could apply for 5 secondswhile sitting on a chair, with the arm supported next to the trunk, elbow in 90° flexion and forearm in a neutral position, wrist in 30° extension and 15° ulnar deviation position. Three repetitions were performed for both hands, and the average value was recorded.

In the second part, the maximal SRP force was measured. The sailors were asked to hold the force measurement sensor with the sheet rope grip technique on the hiking bench training equipment adjusted according to the person, in the hiking position, with the feet fixed under the strap, and pull the sheet rope by applying maximum force for 5 seconds. Three repetitions were performed for both hands, and the average value was recorded.

In the third part, the maximal SRP endurance was measured. Participants were asked to grip the apparatus on the hiking bench training equipment and were required to pull with his/her maximum force for 10 seconds. After 5 seconds of rest, the subject repeated the test with the other hand (five pulls for each hand). During the maximum strength and endurance tests, sailors performed a maximum voluntary contraction with their upper body parallel to the ground in the hiking position.

Figure 4.
Hand Grip Strength in the Sitting Position.

Figure 5.
Hand Grip and Sheet Rope Pulling Strength in the Hiking Position.

Data Analysis

The load cell data of hand grip strength, which was recorded with a sampling frequency of 15 Hz, was filtered using a low-pass fourth-order Butterworth filter at a cut-off frequency using Matlab 2021b software. Subsequently, the filtered signals were separated into right and left hand-grip forces utilizing the 1 kg threshold technique. For further statistical analysis, the maximum mean was obtained by sliding 1-second windows via the force-time data with an overlap rate of 0.75. In addition to 1 seconds of maximal mean data, the average force for the entire duration (5 seconds) of the hand grip strength test was also calculated.

To quantify endurance levels for hand grip and SRP during hiking position, a linear regression curve was constructed on these filtered signals, and the slope value of this curve was calculated. A negative slope value indicates that the signal is in a downward direction, while a positive slope value indicates that the signal is in an upward direction. A high absolute slope value indicates a high rate of change in the signal. By calculating the slope values of the regression curve, the endurance levels of the athletes were quantified.

Statistical Analysis

The Statistical Package for Social Sciences version 26.0 software (IBM Corp.; Armonk, NY, USA) was used to analyze the results of the study. The Shapiro-Wilk test indicated that all data were normally distributed. However, given the sample size, non-parametric tests were employed for correlation and pairwise comparisons. The repeated measures ANOVA test was preferred for three-way factor analysis, for which there is no non-parametric equivalent. Wilcoxon Test was used to determine the statistical differences between the right and left hand, and the Spearman correlation test was used to examine the relationship between hand grip strength and pulling force values. In the examination of the force values obtained in this study with three-factor repeated measurements, the interaction between factors and the ANOVA test used in the evaluation of the statistical difference between variables, the first factor was determined as the Force factor formed by hand grip and SRP in the hiking position, the second factor as the Side (right, left) factor, and the third as the Rep (repetition) factor. According to the results of Mauchly's sphericity test, the assumption of sphericity was accepted. The LSD test correction, which is one of the post hoc evaluations, was used to express which parameters were different and $p < .05$ was considered statistically significant.

Results

The maximum and average value for 5 seconds of 17 sailors in the hand grip, HGHB, and SRP are presented as kilograms (kgs) in Table 1. No significant difference was found in left and right comparisons based on the Wilcoxon signed-rank test. Each force parameter had a positive significant relationship between the right and left hand. In addition, a significant relationship was found between the hand grip in the hiking position and the hand grip sitting position between the right and left hands except between the right hand grip in the sitting position and the left hand grip in the hiking position (Table 2). Significant relationships were found between grip strength for both hands and body weight, grip strength for the left hand and BMI, and finally a significant relationship was found between SRP strength for the right hand and body weight (Table 3).

Table 1.
The Mean ± S.D. Values of Hand Grip and Sheet Rope Pulling

	Maximum Value		Average Value for 5 seconds	
Tests	**Right**	**Left**	**Right**	**Left**
Hand grip (kg)	29.42 ± 6.87	29.98 ± 4.79	28.34 ± 6.98	28.43 ± 4.56
Hand grip on the hiking bench (kg)	29.91 ± 5.66	28.96 ± 5.54	23.96 ± 9.16	22.79 ± 8.45
Sheet rope pulling (kg)	25.54 ± 9.41	24.73 ± 9.84	28.32 ± 5.66	27.24 ± 6.08

Note: S.D. = standard deviation.

The mean and standard deviation of the slope values are given in Table 4. The results of the three-way Repeated Measures ANOVA indicate that there was no significant difference in the interaction of Force × Side × Rep (Table 5). There was a significant difference for the Force × Side interaction and a medium effect size $\eta^2 = .108$ was found. The post hoc test of the general linear model indicates that HG (Right) had a lower slope value than HG (Left) as well as SRP (Right). No significant difference was found between the repetitions of the hand grip and SRP slope values.

Discussion

This study aimed to investigate the correlation among hand grip strength in seated as well as hiking positions and SRP strength among laser class sailors for both hands. In addition, multi-factorial investigations were conducted to assess endurance levels for hand grip and sheet rope pull in the hiking position. Although no significant difference was found for maximum strength, a statistically significant difference in endurance levels was found for the Force × Side interaction according to post hoc comparisons. Additionally, a positive relationship was observed between the right and left hands for each strength parameter even though no statistically significant relationship was found between hand grip and sheet rope strength in either hand. These findings support our hypothesis regarding the relationship between the left and right hand grip but do not confirm that greater grip strength will lead to increased rope-pulling force.

In an investigation conducted by Barrionuevo et al. (2007), potential variances in maximal hand grip strength and muscular endurance between sailors and non-sailors in their dominant and non-dominant hands (Barrionuevo Vallejo et al., 2007). Similar to our study results, no significant difference was found, despite the higher strength and endurance levels for the dominant than the non-dominant hand.

A study conducted by Caraballo (2020) investigated the hand grip strength asymmetries of windsurfing, optimist, and laser-class sailing

Table 2.
The Relationship Levels of Hand Grip, Hand Grip on the Hiking Bench, and Sheet Rope Pulling Strength (Maximum Values for Hand Grip Were Accounted for Analysis)

			Hand Grip (kg)		Hand Grip on the Hiking Bench (kg)		Sheet Rope Pulling (kg)	
Tests			**Right**	**Left**	**Right**	**Left**	**Right**	**Left**
Hand grip (kg)	Right	*r*	1	**.806****	**.663****	.477	.181	.223
		p	–	.000	.004	.053	.488	.389
	Left	*r*	**.806****	1	**.586***	**.484***	.103	.151
		p	.000	–	.013	.049	.694	.562
Hand grip on the hiking bench (kg)	Right	*r*	**.663****	**.586***	1	**.692****	.342	.287
		p	.004	.013	–	.002	.178	.264
	Left	*r*	.477	**.484***	**.692****	1	−.172	−.163
		p	.053	.049	.002	–	.509	.532
Sheet rope pulling (kg)	Right	*r*	.181	.103	.342	−.172	1	**.959****
		p	.488	.694	.178	.509	–	**.000**
	Left	*r*	.223	.151	.287	−.163	**.959****	1
		p	.389	.562	.264	.532	**.000**	–

Note: p = Significance value; *r* = Correlation coefficient. The values indicated as bold specifies significant positive correlation. **$p < .01$; *$p < .05$.

Table 3.
The Relationship Levels Between Anthropometric Characteristics and Strength Levels

			Age (years)	Body Weight (kg)	Height (cm)	BMI (kg/m²)
Hand grip (kg)	Right	*r*	.216	**.533***	.265	.444
		p	.406	**.028**	.304	.074
	Left	*r*	.074	**.538***	.223	**.496***
		p	.777	**.026**	.390	**.043**
Hand grip on the hiking bench (kg)	Right	*r*	.440	.441	.208	.372
		p	.077	.076	.424	.141
	Left	*r*	.378	.448	.217	.373
		p	.134	.072	.404	.141
Sheet rope pulling (kg)	Right	*r*	.377	**.497***	.465	.223
		p	.136	**.42**	.060	.390
	Left	*r*	.286	.443	.424	.200
		p	.265	.075	.090	.441

Note: BMI = Body mass index; *r* = Correlation coefficient; *p* = Significance value. The values indicated as bold specifies significant positive correlation.
$^*p < .05$.

athletes (Caraballo et al., 2020). It was reported that there was no difference between the three class groups when the functional asymmetry values of grip strength were compared. A higher strength level was found for the right hand of the sailors in windsurfing, optimist, and laser classes, 60%, 79%, and 47% respectively. While it is known that the dominant side in the upper extremity is usually the right side, 88.2% of the athletes participating in our study were right-dominant (Malina & Buschang, 1984). Similar to these studies, although there was no significant difference in terms of SRP and hand grip strengths on the hiking bench, a higher strength level in the right hand in our study. Philippe (2021) examined the physical parameters of performance indicators during a sailing race to identify the difference between elite and non-elite sailors (Philippe et al., 2021). It was reported that elite athletes had higher hand grip strength values and higher isometric maximal voluntary strength relative to body weight than non-elite athletes.

Table 4.
The Slope Values of Hand Grip and Sheet Rope Pulling During the Endurance Test in the Hiking Position

	Side	Repetition	Mean ± S.D.
Hand grip	Right	R1	−0.11 ± 0.11
		R2	−0.12 ± 0.06
		R3	−0.11 ± 0.09
		Total	−0.11 ± 0.09
	Left	R1	−0.04 ± 0.1
		R2	−0.09 ± 0.08
		R3	−0.05 ± 0.04
		Total	−0.06 ± 0.08
Sheet rope pulling	Right	R1	−0.05 ± 0.11
		R2	−0.03 ± 0.05
		R3	−0.05 ± 0.08
		Total	−0.04 ± 0.08
	Left	R1	−0.03 ± 0.1
		R2	−0.03 ± 0.07
		R3	−0.05 ± 0.1
		Total	−0.04 ± 0.09

Note: R1, R2, and R3 are first, second, and third repetitions; total refers to mean and standard deviation of all three repetitions.

Table 5.
The General Linear Model of Hand Grip and Sheet Rope Pulling in Right and Left Sides During Three Repetitions

	GLM		
Interactions	Sig.	η^2	Post Hoc
Force × Side × Rep	NS	–	–
Force × Side	$p = .038$	.108	HG(Right) < HG(Left)$^{\Delta}$ HG(Right) < SRP(Right)$^{\Delta}$
Force × Rep	NS	–	–
Side × Rep	NS	–	–

Force factor indicates hand grip (HG) and sheet rope pulling (SRP). The side factor indicates right and left. The Rep factor indicates three repetitions.GLM = General linear model; Sig. = Significance value; η^2 = Partial eta squared: 0.01–0.06 small effect, 0.06–0.14 medium effect, 0.14 < large effect; $^{\Delta}$ = Significant difference; NS = No significance.

Regarding the anthropometric parameters, studies reported that age, body mass index, and height are indicators of hand grip strength and a positive correlation between hand grip strength and body mass index was found in adolescents (Charles et al., 2006; Luna-Heredia et al., 2005; Massy-Westropp et al., 2011). Similar to these studies, our study found a relationship between anthropometric and strength parameters (Table 3). It is considered that the most important factor influencing hand grip strength is the body mass index, and this may be due to the increasing muscle mass of athletes in this age group. In contrast to our study, Sartorio et al. (2002) reported hand grip strength was positively correlated to age in children (Sartorio et al., 2002). This difference could be due to the limited age range of the athletes participating in the study.

The right hand grip endurance levels applied by the athletes using the forearm muscles were found to be lower than the left hand. It could probably be considered that they compensate by applying more SRP force through the elbow flexor muscles. In addition, it may be explained by the higher distribution of strength-developed and fast-fatigable muscle fibers on the dominant side (Sanchis-Moysi et al., 2010). In contrast to a previous study in which the endurance levels of sailors were evaluated (Barrionuevo Vallejo et al., 2007), it is possible that the lower endurance level observed on the right side in our study was because the simulated position of hiking Laser Class sailing athletes would employ sport-specific compensation mechanisms. In addition, sailors in training periods may have shown lower endurance levels for their right side due to the higher central and peripheral fatigue levels.

Conclusion and Recommendations

Based on the results of the study, it is concluded that the sailors performed asymmetrical endurance levels for hand grip. Therefore, upper extremity endurance-based exercises should be integrated into training regimes to reduce asymmetries that could lead to injury.

The study is limited by its small sample size which may result in the inability to detect statistically significant differences in certain parameters. Therefore, further investigations are required to evaluate the strength parameter in larger groups of sailors. Furthermore, further studies could benefit from implementing waterproof equipment to facilitate measurements while the boat is in the water. It is recommended that investigations be carried out into hand grip and SRP strength, as well as core muscle strength during the hiking position.

Availability of Data and Materials: The data that support the findings of this study are available on request from the corresponding author.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Marmara University (Approval no: 09.2021.1236, Date: 23.12.2021).

Informed Consent: Written informed consent was obtained from all participants, their parents and coaches.

Peer-review: Externally peer-reviewed.

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