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Profiling Shoulder Strength in Youth Surfers: Implications for Injury Prevention and Performance Enhancement

Perfilar la fuerza del hombro en surfistas jóvenes: implicaciones para la prevención de lesiones y la mejora del rendimiento

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Abstract. The scapular region has the highest incidence of acute injuries in surfing. However, little is known about the shoulder strength profile in surfers. The aim of this research was to establish the profile of internal and external rotation strength in a group of youth surfing athletes. Methods: Isometric shoulder internal and external rotation strength was measured using a portable dynamometer in 41 (19 boys and 22 girls) youth surfing athletes (13.3 ± 2.1 years, 49.3 ± 9.8 kg, and 157.4 ± 9.5 cm). Regardless of gender, no significant differences were found between shoulder internal and external rotation strength. However, bilateral internal rotation strength was greater than external rotation strength. When comparing boys and girls, statistically significant differences were only found for the left-arm internal rotation strength when adjusted for body mass. Boys exhibited more strength than girls in all situations. No differences were observed based on the surfer's stance. The data from this research provides valuable information for coaches and trainers working with young surfers, allowing a deeper understanding of the specific shoulder strength profile, to support a more effective development of training programs.
Keywords: isometric strength; shoulder internal and external rotation ratio; strength ratio; surfing.

Resumen. Propósito: esta investigación tuvo como objetivo establecer el perfil de la fuerza de rotación interna y externa del hombro en un grupo de atletas jóvenes de surf. Métodos: se midió la fuerza isométrica de rotación interna y externa del hombro utilizando un dinamómetro portátil en 41 (19 niños y 22 niñas) atletas jóvenes de surf (13,3 ± 2,1 años, 49,3 ± 9,8 kg y 157,4 ± 9,5 cm). Resultados: independientemente del sexo, no se encontraron diferencias significativas entre la fuerza de rotación interna y externa del hombro. Sin embargo, la fuerza de rotación interna fue bilateralmente mayor que la fuerza de rotación externa. Al comparar niños y niñas, solo se encontraron diferencias estadísticamente significativas para la fuerza de rotación interna del brazo izquierdo cuando se ajustó por masa corporal. Los niños mostraron más fuerza que las niñas en todas las situaciones. No se observaron diferencias según la postura del surfista. Conclusiones: los datos de esta investigación proporcionan información valiosa para los entrenadores y preparadores físicos que trabajan con surfistas jóvenes, permitiendo una comprensión más profunda del perfil específico de fuerza del hombro, para un desarrollo más efectivo de los programas de entrenamiento.
Palabras clave: fuerza isométrica; relación de rotación interna y externa del hombro; relación de fuerza; surf.

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Introduction

Surfing is an economic, social, and sporting phenomenon experiencing progressive growth worldwide. It is associated with a unique lifestyle, reinforced by the surf industry, which promotes an image of freedom, radicalness, and enjoyment, aligning well with contemporary consumption patterns (Santos, 2022). This attractiveness has led to an increasing number of youth athletes engaging in competitive and recreational surfing activities (Furness et al., 2018).

Due to the physical complexity of surfing and the demands of the marine environment, injuries associated with the sport affect one out of every three recreational surfers, with an average of one acute injury per year (Furness et al., 2015; McArthur et al., 2020; Minghelli et al., 2018). Among several studies conducted on injury prevalence, it has been observed that acute injuries have been increasing, primarily due to aerial maneuvers, while the incidence of chronic injuries, mainly musculoskeletal issues related to paddling technique, is approximately 16.4% (Furness et al., 2015; McArthur et al., 2020; Minghelli et al., 2018).

The high incidence of shoulder injuries is attributed to the demands of surfing activity. Various motion analysis studies reported that paddling constitutes 42% to 54% of the total time spent in a surfing session, with an average paddling time ranging from 16 to 25 minutes (Farley et al., 2017; McArthur et al., 2020; Minghelli et al., 2018). A detailed analysis of surfing paddling, including electromyography, demonstrated striking similarities with the crawl stroke in competitive swimming (Nessler et al., 2019). Given its kinematics and demands during a surf session, paddling exerts significant stress on the shoulder girdle and surrounding musculature, as surfers use alternating upper limb action to propel the surfboard (Langenberg et al., 2021; Mendez-Villanueva & Bishop, 2005; Nessler et al., 2015). Although some research has been directed towards analyzing the physiological demands on surfers during the paddling phase (Nessler et al., 2015), there are few references to the shoulder strength profiles of surfers (Furness et al., 2018; Langenberg et al., 2021).

However, there is evidence of an association between shoulder muscle imbalances or weaknesses and the risk of injury in sports that require preferential use of the dominant upper limb, such as handball (Clarsen et al., 2014), baseball (Byram et al., 2010) and swimming (Wanivenhaus et al., 2012).

Investigating the shoulder's internal and external rotation strength in a group of handball players using isokinetic dynamometry, Clarsen et al., (2014) found that those with muscular imbalances had two and a half times higher chances of suffering a shoulder injury compared to those without such imbalances. A similar analysis using isometric strength and a portable dynamometer (Edouard et al., 2013) determined that reduced isometric shoulder external rotation strength was a significant predictor of increased injury severity related to shoulder injuries. In baseball athletes, reductions in external rotation strength and lower external-to-internal rotation ratios were associated with a higher incidence of shoulder injuries (Byram et al., 2010). Although these sports have different circumstances and environments compared to surfing, the repetitive demands of internal rotation during paddling are evident (Furness et al., 2018; Lassalle et al., 2012).

The risk of shoulder injuries in surfers is largely related to muscle imbalances, scapulothoracic dysfunction, fatigue, and subacromial impingement (Langenberg et al., 2021). There is also evidence that strength ratios play a role in determining athletes at risk of shoulder injuries (Furness et al., 2018; Hurd et al., 2011; Madeira et al., 2019; McArthur et al., 2020). Furthermore, many studies (Andrade et al., 2013; Batalha et al., 2012; Hurd et al., 2011; Johansson et al., 2022; Oliver et al., 2020; Ramsi et al., 2004; Wong & Ng, 2009) have been conducted to record the strength profile of shoulder rotator muscles and establish normative baselines for monitoring changes in these strength patterns. The study from Ramsi et al. (2004) assessed the isometric strength profile of swimmers during a competitive season and demonstrated increased internal rotation strength without equal gains in external rotation from preseason to the end of the season. Hurd et al. (2011) conducted a cross-sectional study on 165 baseball pitchers, providing a strength profile for the internal and external rotators of the shoulder in this young population. The authors concluded that this information can be used by clinicians and researchers to interpret the muscular strength performance in this population.

In surfing, paddling primarily activates the internal rotators and shoulder flexors (Langenberg et al., 2021), potentially leading to muscle imbalances and issues such as scapulothoracic dyskinesis and subacromial pain (Lassalle et al., 2012). Therefore, assessing these muscle imbalances and shoulder strength are essential for injury prevention strategies and can minimize muscular asymmetry and enhance performance (Furness et al., 2018; Langenberg et al., 2021; Lassalle et al., 2012). Despite investigations into the strength profiles of the shoulder's internal (IR) and external rotation (ER) in some sports, to the authors' knowledge, only two studies have evaluated shoulder rotation strength in surfers (Furness et al., 2018; Madeira et al., 2019), and there is no such reference for youth surfing athletes.

Giving the importance of understanding shoulder health, as well as the need for targeted training and rehabilitation programs tailored for the surfing community, it is essential for enhancing performance and athlete development (Furness et al., 2018; Madeira et al., 2019), as well as for the prevention and management injuries (Langenberg et al., 2021; Lassalle et al., 2012). Therefore, it seems opportune to establish a profile of shoulder internal and external rotation strength for young surfers. Moreover, providing detailed information will aid more informed clinical decision-making and supporting surfer recovery, allowing coaches and sports coaching and development stakeholders from other sports to implement more effective training strategies. This comprehensive approach will not only help in prescribing targeted interventions and support surfer recovery, but also document more effective training strategies in preventive strategies and reducing the incidence of injuries. Therefore, the objective of this study was to establish the profile of shoulder internal and external rotation strength in a group of youth surfing athletes.

Materials and methods

Population

In total, 41 surfing athletes (19 boys e 22 girls) participed in this study which comprised an average of three surfing training for week with approximal 2 hours (Table 1).

Table 1
Sample characterization - mean (standard deviation)

	Total Sample (n=41)	Boys (n=19)	Girls (n=22)
Age (years)	13.3 (2.1)	13.2 (2.0)	13.5 (2.3)
Surf experiencie (years)	2.4 (1.6)	2.3 (1.2)	2.5 (1.5)
Height (centimeters)	157.4 (9.5)	156.2 (10.9)	158.6 (7.9)
Weight (kilograms)	49.3 (9.8)	49.5 (11.7)	49.0 (7.2)
Body Mass Index (kilograms per square meter)	19.5 (2.0)	19.1 (1.8)	19.8 (2.3)
Percentage of Body Fat	20.5 (5.8)	16.5 (2.8)	24.2 (5.4)*
Percentage of Muscle Mass	35.8 (4.3)	39.1 (3.4)*	32.8 (2.4)
Basal Metabolic Rate (kilocalories)	1376.1 (127.7)	1448.7 (134.8)*	1309.1 (76.4)

* $p < 0.05$

All participants passed the annual sports medical examination, had no injuries or pain in the shoulder area in the 5 days prior to the evaluation, and regularly participated in local and regional surfing competitions, with surfing being their main sport. The athletes train regularly at the Surfing Viana High Performance Center.

Evaluation

The data collection comprises socio-demographic and surfing profile questionnaire, training habits, shoulder pain in the five days prior the evaluation, body composition and internal and external isometric shoulder strength.

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Participants were evaluated by a team of three experimented evaluators, under the coordination of a PhD in Sports Science with more than 10 years of experience in developing physical evaluations in different populations.

The evaluators take place in the training room of the Surfing Viana High Performance Center, ensuring a familiarity with the technique and protocol for using the data collection instrument (Furness et al., 2018). The local Institutional Review Board gave their ethical clearance (CTC-ESDL-CE001-2020). Data collection was included in its strategic and sports development plan. All participants agreed to participate, and informed consent was obtained from their legal guardians.

Body Composition

Body mass in kilograms (kg), body fat percentage, and muscle mass were assessed using an Omron BF511 bioimpedance scale (Omron Healthcare Co. Ltd., Japan), at a frequency of 50 kHz (500 uA) following strictly standardized conditions,as defined by the manufacturer, with rounding to 0.1 kg (Pietiläinen et al., 2013). Participants' height was assessed with an accuracy of 0.1 centimeters using a wall stadiometer with a headpiece (SECA 206, Germany). All participants were dressed in light clothing and barefoot, with their heads oriented according to the Frankfurt plane standard.

Isometric Strength

The shoulder strength profile, internal and external rotation, was assessed using a handheld dynamometer (MicroFET 2 HOGGAN Scientific LLC, Salt Lake City, USA). For each repetition, the dynamometer was prepared with the appropriate support for the participant's forearm and programmed to record the maximum force reached in Newtons (N). The evaluator performed the evaluation with the dynamometer in their hand in a stationary manner, according to a fixing tape for their hand, while the participant exerted maximum force. According to the validated protocol developed by Furness and collaborators specifically for surfers (Furness et al., 2018), the participant will be positioned on a treatment table, in a prone position, with the Upper Limb (UL) to be tested positioned laterally, while the opposite UL is positioned so that the participant places their forehead on their hand in order to establish the neutral position of the spine (Figure 1).

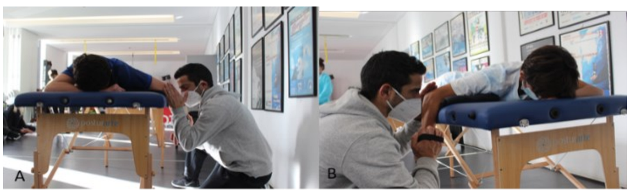

Figure 1. Evaluator Positioning for Isometric Shoulder Strength Testing (A - Internal Rotation; B - External Rotation)

The shoulder to be tested was positioned approximately 90° of abduction and 90° of elbow flexion with the palm of the hand open and neutral rotation of the shoulder, with a towel supporting the weight of the arm on the treatment table (Figure 1). The evaluator maintains a supportive position in front of the direction of movement, with the dynamometer placed in the examiner's hand closest to the treatment table. The other hand was used to stabilize the participant's elbow, limiting compensatory abduction or adduction of the glenohumeral joint. The dynamometer was placed approximately 2 cm from the radial styloid process on the ventral (internal rotation) or dorsal (external rotation) aspect of the participant's distal forearm. Before performing the evaluation, the participant was familiarized with the movement. The examiner passively moves the arm to be tested through the appropriate action, and then the participant performs the movement, but only at about 50% of their maximum force. Once they have demonstrated that they understand how to perform each movement, two repetitions are performed, in the order of IR and ER of the right upper limb (UL), followed by the same structure for the left UL. For each execution, the participant was asked to perform their maximum force, ensuring at least 3 seconds of contraction. After each repetition, a 10-second rest period is allowed, and a 30-second rest period between the tests of each individual movement.

The test was performed after a specific and standardized warm-up consisting of two arm circumduction exercises, three shoulder girdle mobilization exercises, followed by positioning on the treatment table and performing the test adaptation protocol. During the test, verbal instructions and encouragement are always provided to the participant, starting the test with a countdown of "1-2-3-begin" and maintaining consistent tone and volume of verbal encouragement with the phrase "push-push-push-push-relax".

Throughout the evaluation, the following factors are always ensured: 1.the evaluator maintains a comfortable and stable position to ensure support for the participant's elbow and to be able to withstand the force produced; 2. the dynamometer was calibrated, and the units of measurement in Newtons; 3. the participant's cervical spine was in a neutral position; 4. participant has been informed and understands that they should exert maximum effort, maintaining constant tension during the 3 seconds of contraction; 5. the evaluator provides verbal and non-verbal encouragement for the participant to produce maximum force throughout the test; 6. the warm-up and rest times during testing were accomplished.

Statistical Analyses

Descriptive statistics were calculated to provide a profile for each factor, expressed as mean and standard deviation. The ratio between IR and ER strength was determined by dividing the maximum IR strength by the ER strength of each upper limb individually. The same procedure was considered to normalize the maximum IR and ER strength of the upper limbs relative to body mass, considering here the force to be divided by the body mass. The assumption of normality was verified using the Shapiro-Wilk test. According to the non-normal distribution of the variables under study, the Mann-Whitney non-parametric test was performed considering gender and the fact of being regular or goofy in their surfing stance. All statistical analyses were performed using the SPSS software (version 26 for Windows, IBM, USA) with a 95% confidence level.

Results

As observed in Table 1, statistically significant differences were found in body composition, with girls presenting higher values for body fat percentage and body mass index, while boys have higher levels of muscle mass.

Table 2.
Shoulder Internal and External Rotation Isometric Strength Characterization - Mean (Standard Deviation)

	Total Sample (n=41)	Boys (n=19)	Girls (n=22)
Internal Rotation Strength Right Upper Limb (Newtons)	136.5 (34.5)	144.0 (39.5)	127.8 (26.2)
External Rotation Strength Right Upper Limb (Newtons)	128.6 (31.6)	132.1 (35.0)	124.5 (27.5)
Internal Rotation Strength Left Upper Limb (Newtons)	144.6 (34.2)	153.4 (39.3)	134.5 (24.4)
External Rotation Strength Left Upper Limb (Newtons)	116.3 (29.4)	121.8 (34.1)	110.1 (22.0)
Internal Rotation Strength Right Upper Limb (Newtons/kilogram)	2.8 (0.7)	3.0 (0.8)	2.6 (0.5)
External Rotation Strength Right Upper Limb (Newtons/kilogram)	2.7 (0.6)	2.7 (0.7)	2.6 (0.6)
Internal Rotation Strength Left Upper Limb (Newtons/kilogram)	3.0 (0.6)	3.2 (0.6)*	2.8 (0.5)
External Rotation Strength Left Upper Limb (Newtons/kilogram))	2.4 (0.6)	2.5 (0.6)	2.3 (0.5)
Internal Rotation to External Rotation Ratio Right Upper Limb	1.1 (0.2)	1.1 (0.2)	1.0 (0.2)
Internal Rotation to External Rotation Ratio Left Upper Limb	1.3 (0.2)	1.3 (0.2)	1.3 (0.2)

* p= 0.047

Observing the values related to isometric RI and ER strength (Table 2), statistically significant differences were found when comparing boys with girls for the RI variable of the left UL when adjusted for shoulder internal rotation strength to body mass, with boys presenting more force than girls.

Performing the same analysis adjusted for the fact that participants have a surfing stance, either regular or goofy, there were no statistically significant differences. It is observed that regardless of the adjustment or gender, the IR strength presents a generally higher profile than the ER strength.

Discussion

The objective of this study was to establish a profile of Internal Rotation (IR) and External Rotation (ER) strength in youth surf athletes. Analyzing the shoulder isometric forces, it was observed that boys always show higher force values in all the movements analyzed. It is also observed that IR values are always higher than ER values, regardless of gender, upper limb (left or right), and adjustment for body weight. As expected, the results are similar those found in other populations of surfers, when evaluated using the same method (Furness et al., 2018) or even with an isokinetic dynamometer (Madeira et al., 2019). In fact, the differences between IR and ER are consistent and derive from the fact that in specific surfing paddling, the muscles that are most active are mainly the internal rotators and the muscles involved in shoulder flexion. This implies that the pectoralis major and the subscapularis are therefore more recruited against the resistance of the water, while the external rotators are used only against gravity (Langenberg et al., 2021). Another important aspect is the fact that, unlike swimming, there is no axial rotation of the spine, which leads to the erector spinae providing stability for shoulder flexion and elbow extension in surfers (Nessler et al., 2015). This leads to a scapular tilt and lateral rotation that can result in limited external rotation, with implications for the appearance of scapular pain and limited activation of the muscles involved in shoulder IR (Langenberg et al., 2021).

Analyzing the symmetry between upper limbs, can be observe that boys present a positive differential in IR, comparing the left upper limb with the right, of nine (9) Newtons. In girls, this differential was seven (7) Newtons. In the same line of analysis, ER, comparing the right upper limb with the left, has a result of twelve (12) Newtons in boys and fourteen (14) Newtons for girls, but in this case, with the right upper limb presenting higher values. Considering this data and that per two-hour surf training session approximately eighty-five minutes spent paddling (Secomb et al., 2015), it is clear that these athletes, even as young surfing athletes, already present adaptations specific to the sport, but in a magnitude higher than that found in swimmers (Boettcher et al., 2020). It is known that IR is performed in the propulsive phase of paddling (Langenberg et al., 2021), necessarily leading to an increase in IR strength. However, this factor does not explain why the IR values of the left UL are higher than those of the right UL, which was not found in the study by Furness et al., (2018). This may indicate that can be mediated by the lack of experience of these athletes, related to the fact that the training locations for excellence for this group provide a majority of waves with characteristics for right-side surfing, which implies that the left UL has a predominance in the maneuver of directing the board due to the adjustment of the board and the start of the power paddle to enter the wave. However, being regular or goofy in the stance does not have any influence on the IR and ER strength of the shoulder.

Other studies similar to this (Cools et al., 2016; Furness et al., 2018) have normalized strength values to body mass in order to mitigate gender differences, although with different results than expected. Boys demonstrate to be stronger even normalizing strength to body mass, with an accentuation of the differences. This may mean that in surf youth athletes there is an adjustment of IR strength mainly to the left and more significantly in boys, proven by the significant change found when comparing the IR of the left UL between boys and girls after normalization for body mass. This finding reinforces the previous observation regarding a greater strength found in the left UL compared to the right, also explained by the greater body mass and muscle mass of boys compared to girls. To address the asymmetries of the upper limbs, it will be important for coaches and other professionals involved in the training and recovery of these athletes to promote the performance of specific exercises that reduce the difference between IR/ER with targeted strengthening exercises for the external rotators to promote a more symmetrical profile, so that the IR/ER ratio is closer to one (1), thus reducing the risk factors for injury (Lassalle et al., 2012).

As with any research, there are some limitations to be addressed. Firstly, it is not possible to standardize training routines and the differences between sample size and distribution, placing limitations on generalizability, although it can be considered for youth surf athletes. It is also needed to consider that the test was conducted in a controlled environment, following previously validated procedure for this populations (Furness et al., 2018). However, it lacks some ecological validity, meaning that the muscle engagements might not accurately reflect the muscle activation patterns and strength utilized during actual surfing paddling. Environmental factors such as wave conditions, water temperature, and wetsuit, which significantly affect muscle performance and fatigue (Barlow et al., 2014; Langenberg et al., 2021; Nessler et al., 2015), are not replicated in this controlled setting. This limitation highlight that isometric shoulder assessment do not capture all the dynamic, sport-specific movements (Klingner et al., 2022) and the various social and environmental factors (Dann et al., 2024), crucial in surfing performance. Therefore, while isometric assessments provide valuable baseline data, they should be complemented with more dynamic, sport-specific tests, align with a Representative Learning Design (Dann et al., 2024) that ensure a more comprehensive evaluation of a surfer's. Future research should include a larger group of surfers and control the maturation status, confirming this reality and provide more robust recommendations.

The data also suggest some practical implications to be considered in the training of young surfers. First, the need for targeted strength training that focuses on balancing the ratio between external and internal rotators to improve shoulder stability. Second, the need for emphasizing exercises for the left arm in male surfers is particularly important, given the observed trends in strength discrepancies. Third, the need for regular assessments of shoulder strength and mobility patterns are essential to identify imbalances early and mitigate the potential interference in injury risk, with a specific focus on incorporating stretching routines for internal rotators. Regular assessments of shoulder strength and mobility patterns are essential for early identification of imbalances, helping to develop specific programs that address the balance between external and internal rotators, that in collaboration with physiotherapists can lead to more tailored recovery plans after injury. Coaches must be educated about the specific shoulder health and injury prevention needs of surfers, utilizing reliable assessment tools to effectively monitor shoulder strength. By implementing these strategies, surfing stakeholders cannot only enhance performance but also promote long-term surfer's health, ensuring a sustainable career development in youth surfing athletes.

Conclusions

Youth surf athletes present consistently higher IR strength than ER strength in both arms, regardless of gender or preferred surfing stance (regular or goofy). While there were no significant differences between boys and girls overall, a trend emerged, where boys mostly have greater IR strength in their left shoulder compared to girls. The data from this research provides valuable information for coaches and trainers working with young surfers, allowing a deeper understanding of the specific shoulder strength profile, to support more effective development of training programs. Based on this observed trend, these programs should focus on strengthening shoulder external rotators, with particular attention to the left shoulder for boys.

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