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Artículos

Shoulder pain and disability predict clinical outcomes better than biomechanical and functional measures in young swimmers: a prospective cohort study

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ABSTRACT

Objective: This study investigated the association between shoulder pain, disability and functional measures in young competitive swimmers to identify risk factors for pain occurrence. **Methods:** In this prospective study, 32 swimmers (13–16 years) underwent clinical and functional assessments, including the Western Ontario Shoulder Instability Index (WOSI) and Upper Quarter Y Balance Test (UQ-YBT) performed on a force platform, with postural displacements quantified as resultant distance path length. Shoulder pain was self-reported after six months via telephone follow-up. **Results:** After six months, 9 (28%) swimmers reported shoulder pain within 6 months. Swimmers with shoulder pain showed higher WOSI scores (physical symptoms, sports/recreation, emotional domains, and total score), indicating greater dysfunction. UQ-YBT performance and balance measures showed no significant group differences. Logistic regression identified WOSI subscales as significant predictors of shoulder pain, with higher scores increasing the odds of pain occurrence. Age was also a predictor, with younger athletes at slightly higher risk. **Conclusion:** Clinical assessments like WOSI are better than functional tests in predicting shoulder pain risk in young swimmers, underscoring the importance of monitoring symptom-related disability for early prevention.

Keywords: pain perception; physical functional performance; sports medicine; health risk; postural control; youth sports.

El dolor y la discapacidad del hombro predicen mejor los resultados clínicos que las medidas biomecánicas y funcionales en nadadores jóvenes: estudio de cohorte prospectivo

RESUMEN

Objetivo: Este estudio investigó la asociación entre dolor de hombro, discapacidad y medidas funcionales en jóvenes nadadores competitivos para identificar factores de riesgo para la aparición del dolor. **Métodos:** En este estudio prospectivo, 32 nadadores (13–16 años) se sometieron a evaluaciones clínicas y funcionales, incluidos el Índice de Inestabilidad del Hombro de Western Ontario (WOSI) y la Prueba de Equilibrio Y de Cuadrante Superior (UQ-YBT), realizada en una plataforma de fuerza, con los desplazamientos posturales cuantificados como longitud de la trayectoria resultante. El dolor de hombro fue autoinformado después de seis meses mediante seguimiento telefónico. **Resultados:** A los seis meses, 9 (28%) nadadores reportaron dolor de hombro. Los nadadores con dolor de hombro mostraron puntuaciones más altas en el WOSI (síntomas físicos, deporte/recreación, dominios emocionales y puntuación total), lo que indica una mayor disfunción. El rendimiento en el UQ-YBT y las medidas de equilibrio no mostraron diferencias significativas entre los grupos. La regresión logística identificó las subescalas del WOSI como predictoras significativas del dolor de hombro, con puntuaciones más altas que aumentaban las probabilidades de aparición del dolor. La edad también fue un predictor, con los atletas más jóvenes presentando un riesgo ligeramente mayor. **Conclusión:** Las evaluaciones clínicas como el WOSI son mejores que las pruebas funcionales para predecir el riesgo de dolor de hombro en jóvenes nadadores, lo que subraya la importancia del monitoreo de la discapacidad relacionada con los síntomas para la prevención temprana.

Palabras clave: percepción del dolor; rendimiento funcional físico; medicina deportiva; riesgo para la salud; control postural; deportes juveniles.

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A dor e a incapacidade do ombro predizem melhor os resultados clínicos do que as medidas biomecânicas e funcionais em nadadores jovens: estudo de coorte prospetivo

RESUMO

Objetivo: Este estudo investigou a associação entre dor no ombro, incapacidade e medidas funcionais em jovens nadadores competitivos, a fim de identificar fatores de risco para a ocorrência de dor. **Métodos:** Neste estudo prospectivo, 32 nadadores (13–16 anos) foram submetidos a avaliações clínicas e funcionais, incluindo o Índice de Instabilidade do Ombro de Western Ontario (WOSI) e o Teste de Equilíbrio Y de Quadrante Superior (UQ-YBT), realizado em uma plataforma de força, com os deslocamentos posturais quantificados como comprimento da trajetória resultante. A dor no ombro autorrelatada foi registrada após seis meses, por meio de acompanhamento telefônico. **Resultados:** Após seis meses, 9 (28%) nadadores relataram dor no ombro. Nadadores com dor no ombro apresentaram escores mais altos no WOSI (sintomas físicos, esporte/lazer, domínios emocionais e escore total), indicando maior disfunção. O desempenho no UQ-YBT e as medidas de equilíbrio não apresentaram diferenças significativas entre os grupos. A regressão logística identificou as subescalas do WOSI como preditoras significativas da dor no ombro, com escores mais elevados aumentando as chances de ocorrência de dor. A idade também foi um preditor, com atletas mais jovens apresentando risco ligeiramente maior. **Conclusão:** Avaliações clínicas como o WOSI são mais eficazes do que testes funcionais para predizer o risco de dor no ombro em jovens nadadores, destacando a importância do monitoramento da incapacidade relacionada aos sintomas para a prevenção precoce.

Palavras-chave: percepção da dor; desempenho funcional físico; medicina esportiva; risco à saúde; controle postural; esportes juvenis.

Introduction

Swimming demands repetitive and intense shoulder rotation movements. Elite swimmers may cover up to 14,000 meters/week, performing around 16,000 rotations weekly, placing significant strain on joint structures.[1] The shoulder complex consists of four joints and several muscles, and its integrity ensures stability and movement precision. Pain or injury-related changes can compromise motor control and the kinematics of this joint complex, predisposing it to dysfunction.[2] Consequently, pain (defined as an "unpleasant sensory and emotional experience"[3]) in shoulder complex is reported by 40-91% of athletes, and it is an early sign of overload or incipient injury.[4] This high incidence underscores the need for specific preventive strategies for this population.

Early and multidimensional assessments are essential to detect shoulder dysfunction and guide effective prevention and rehabilitation strategies. In this context, Feijen et al.[5] developed a prognostic model for shoulder pain in young swimmers, identifying the acute-chronic workload ratio as the strongest predictor (4.3 times higher risk). Souza et al.[6] had already associated competitive swimming with shoulder pain and signs of impingement and rotator cuff injuries, while Kennedy et al.[7] linked range of motion, laxity, and muscle imbalances to pain, emphasizing age- and level-specific assessments. Finally, Porter and collegues[8] showed that an acute increase in supraspinatus tendon thickness after training predicts pain at 3 and 6 months, reinforcing the importance of individualized monitoring. However, these studies did not investigate measures of shoulder sensorimotor control.

The stability of this joint depends on the interaction between static and dynamic components, mediated by the sensorimotor system,[9,10] and dysfunction in this joint is associated with proprioceptive and neuromuscular control alterations.[2,9] For assessing shoulder sensorimotor control in competitive swimmers, the Upper Quarter Y Balance Test (UQ-YBT) is a valid and reliable tool,[11] encompassing strength, stability, and mobility.[12] Its results are influenced by factors such as maturation and competitive level.[12,13] Recently, Albuquerque et al.[14] integrated a force platform assessment into the UQ-YBT, previously used in static conditions.[15,16] In young swimmers, performance was minimally affected by laterality, while center of pressure displacements was influenced by task demands. Importantly, performance and sensorimotor control on the UQ-YBT were not affected by sex or the presence of shoulder pain at the time of assessment.

The present study aimed to expand on previous findings by prospectively investigating the association between shoulder sensorimotor measures, clinical scores, and functional scores, and the subsequent occurrence of pain in youth swimmers. Considering the multifactorial nature of pain, we sought to identify, among the applied clinical and functional tests, a set of factors that could provide insights into the early identification of shoulder injury risk.

Methods

Ethical considerations

The study was approved by the Institutional Research Ethics Committee prior to its execution (process no. 4.000.902 on April 30, 2020). All parents or guardians of the participants signed an informed consent form after receiving an explanation of the study, and before any procedures were performed.

Study Design

This prospective cohort study was conducted from March to October 2023. The flowchart shown in Figure 1 describes the research protocol. First, athletes were asked to complete an anamnesis and two questionnaires. Subsequently, the Upper Quarter Y Balance Test (UQ-YBT) was performed over a force platform, where participants had to reach in three directions (medial, inferolateral, and superolateral) with each upper limb. Finally, six months later, a follow-up questionnaire was administered to assess shoulder symptoms.

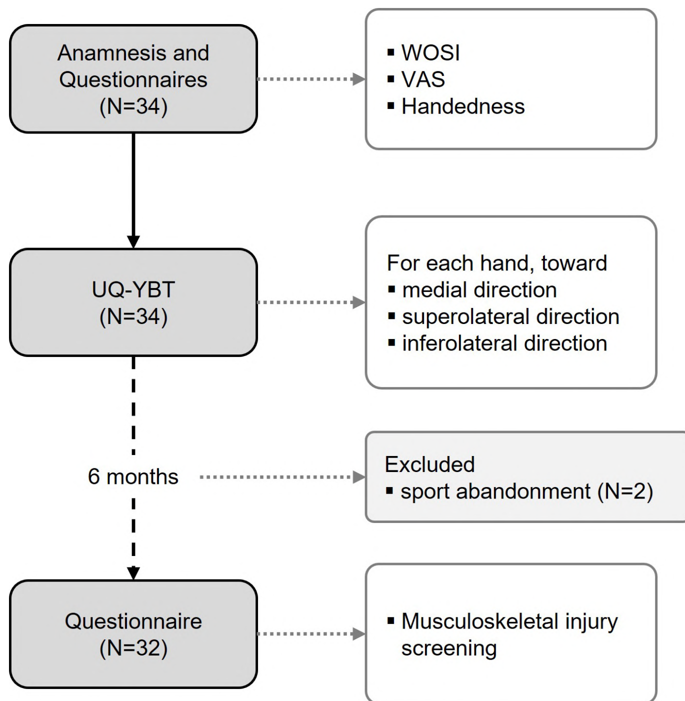

Fig. 1 Flowchart describing the research protocol.

Setting and Participants

The study sample comprises swimming athletes from a local elite sports club, aged 13 to 17 years, who train 5 to 7 times weekly and swim between 3000m and 8000m daily. Exclusion criteria include a history of incapacitating musculoskeletal disorders, neurological conditions, major trauma, or prior surgery on the upper limbs, trunk, or lumbar spine, as well as the current use of anti-inflammatory medication.

Baseline assessment of clinical and functional measures

An interview was taken to collect athletes' sociodemographic, anthropometric, and sports-related information.

Shoulder instability symptoms were assessed using the Brazilian Portuguese version of the Western Ontario Shoulder Instability Index (WOSI),[17,18] which consists of four domains related to: physical symptoms; sports, recreation, and work; lifestyle; and emotional factors. The WOSI contains 21 items, with responses given on a 100-mm visual analogue scale, ranging from "no complaints" (0) to "severe complaints" (100). The items are summed into four scores, with a total score ranging from 0 to 2100, where 0 indicates no limitations and 2100 corresponds to extreme limitations.

To determine the participant's preferred upper limb, we used the Edinburgh Handedness Inventory.[19] This questionnaire was administered in an interview format, where each subject indicates their preferred hand for each of the listed manual activities by selecting the right or left column for their response.

Baseline assessment of Upper Quarter Y Balance Test

First, the upper limb length was measured with a tape measure (precision of 0.5 cm), with participants standing, arms abducted to 90°, elbows extended, forearms in neutral position, and thumbs pointing upward. The measurement was taken from the spinous process of the 7th cervical vertebra to the tip of the middle finger.[13]

Next, the athletes were positioned on a force platform in a push-up posture, with the shoulders and wrists at 90 degrees of flexion, elbows and knees extended, trunk straight, and feet hip-width apart. The head remained in a neutral position, in line with the trunk. In this position, body weight is distributed between the athlete's feet and the supporting hands (randomly assigned as the reaching or supporting limb), which stay in contact with the platform.

After a familiarization period with the procedure, athletes performed the UQ-YBT adapted for the force platform, using a wooden ruler (5 cm in height) positioned in each of the three directions. This test challenges shoulder mobility and stability, requiring the participant to bear weight on the supporting limb on the platform, while reaching with the contralateral limb in the medial, inferolateral, and superolateral directions.[11] Each direction was tested three times in random order, with reach distance and posturographic data recorded. UQ-YBT reach distances were averaged and normalized by upper limb length.

Baseline assessment of postural sway

Center of pressure (COP) coordinates were acquired at 30 Hz using a force platform (Wii Balance Board, Nintendo Co Ltd, Japan). Data was transmitted via Bluetooth to a laptop running a custom LabVIEW program (National Instruments, USA). The platform was calibrated according to the manufacturer's guidelines. The COP signal was resampled to 100 Hz using the SWARII algorithm,[20] converted into resultant distance (square root of the sum of the squared displacements in the lateral and anteroposterior directions), and expressed as path length (summed distances between consecutive points) for each direction.[21] Data processing was performed offline in the Python 3.11.7 environment.

Outcome assessment

After six months, a follow-up phone call was made to assess sports-related shoulder symptoms. The questionnaire evaluated the occurrence of pain in the previous six months, including: specific conditions or activities associated with it; affected body parts; duration of activity suspension; whether treatment was sought; and whether the athlete resumed their usual activities. Athletes were classified as positive (=1) or negative (=0) for pain based solely on reported shoulder symptoms (with/without pain symptoms, respectively).

Statistical analysis

Missing data (approximately 6% of total) from functional assessments (UQ-YBT performance and force platform variables) were addressed using Multiple Imputation by Chained Equations (MICE). Normality assessment indicated that 60% of the variables showed Gaussian distribution (Shapiro-Wilk test, $P>0.062$).

Group comparisons (positive vs. negative shoulder pain symptoms) used Welch's t-tests for unequal sample sizes, with Cohen's d effect sizes being computed (trivial: <0.2; small: 0.2–0.5; moderate: 0.5–0.8; large: >0.8). False Discovery Rate (FDR) correction maintained false positives below 5%.

Variables with large effect sizes ($d>0.8$) entered univariate logistic regression to assess predictive value for pain status. Predictors included age, WOSI subscores (physical symptoms, sports/recreation/work, emotion, and total score), with previous shoulder injury/pain as covariate. Continuous predictors were Z-score normalized (mean=0; SD=1) to allow for direct comparison of effect sizes across different measurement scales. All logistic regression models were fitted using maximum likelihood estimation, with results expressed as odds ratios (OR) with corresponding 95% confidence intervals.

Table 1. Sample characteristics, functional performance and postural displacement during UQ-YBT, by groups (post-6-mo pain report).

	Groups			
	Neg. (N=23)	Pos. (N=9)	P-value*	Cohen-d
Demographics				
Age (years)	14.7 (0.8)	13.8 (0.7)	0.024	1.240
Height (cm)	170.2 (7.3)	166.8 (6.5)	0.251	0.487
Weight (kg)	60.8 (8.7)	55.2 (5.4)	0.104	0.699
BMI (kg/m^2)	20.9 (1.8)	19.8 (1.1)	0.104	0.638
Time of practice (years)	7.0 (1.7)	7.4 (2.4)	0.590	0.251
Training volume (km/week)	7.2 (0.9)	6.7 (0.8)	0.251	0.525
Functional performance				
UQ-YBT-comp., right	94.2 (7.1)	92.6 (9.2)	0.962	0.211
UQ-YBT-comp., left	93.9 (7.7)	91.8 (8.8)	0.962	0.268
UQ-YBT-IL, right	87.1 (7.9)	84.0 (9.3)	0.962	0.373
UQ-YBT-IL, left	85.4 (8.2)	81.1 (10.5)	0.962	0.482
UQ-YBT-ME, right	90.3 (7.3)	89.4 (5.6)	0.962	0.125
UQ-YBT-ME, left	92.6 (8.3)	89.8 (6.8)	0.962	0.359
UQ-YBT-SL, right	81.7 (10.9)	81.4 (13.1)	0.962	0.021
UQ-YBT-SL, left	81.3 (10.0)	81.7 (10.5)	0.962	0.045
Postural displacement				
PL-IL, right	429.7 (162.8)	426.7 (191.3)	0.967	0.018
PL-IL, left	363.4 (89.0)	371.4 (112.0)	0.967	0.084
PL-ME, right	490.0 (229.8)	453.4 (289.5)	0.967	0.148
PL-ME, left	402.7 (133.1)	333.8 (76.0)	0.348	0.571
PL-SL, right	717.2 (228.6)	590.7 (180.8)	0.348	0.583
PL-SL, left	720.6 (270.0)	669.7 (178.9)	0.967	0.204

Data are presented as mean (SD). Neg./Pos., negative/positive shoulder symptoms. *FDR corrected. Right/left, hand on which the test was performed; UQ-YBT, Upper Quarter Y-Balance Test; comp., composite score; IL, inferolateral; ME, medial; SL, superolateral; PL, path length.

All analyses were performed in Python 3.11.7, using the pingouin (version 0.5.5) and statsmodels (version 0.14.0) packages. Statistical significance was set at 5%.

Results

Participants

Thirty-four young athletes were originally enrolled, but two dropped out before the study's completion due to leaving the sport. The study included 32 competitive swimmers (18 female, 14 male) aged (mean and range) 14 (13-16) years, with a body mass of 59.2 (44.0-80.0) kg, height of 169 (158-187) cm, and BMI of 20.6 (15. 8-23.8) kg/m^2. Participants had been swimming for 7 (3-13) years and reported an average training volume of 7.1 (6.0-9.5) km/week. The sample was predominantly right-handed (N=30, 93.8%), with an equal distribution of swimmers with and without a history of previous shoulder injury/pain (N=16). Regarding swimming specialization, the cohort consisted of 17 sprinters, 14 long-distance swimmers, and 1 middle-distance swimmer. The most common stroke was freestyle (N=14), followed by butterfly (N=8), breaststroke (N=5), backstroke (N=4), and individual medley (N=1).

Shoulder pain symptoms after 6 months

Of the total participants, 9 (28%) experienced shoulder pain in the subsequent six months, while 23 (72%) reported no shoulder pain. All affected athletes reported pain during training, with the following distribution: bilateral shoulder pain (N=6), right shoulder pain (N=2), and left shoulder pain (N=1). Regarding physical therapy, seven sought treatments, while two did not. All athletes with shoulder pain symptoms returned to or maintained their regular sports activities without prolonged interruption (at least one day off due to pain was taken). Of the 9 athletes with positive pain symptoms, 6 (67%) had already reported shoulder injury/pain in the previous 6 months; these overlapping was accounted in logistic modeling.

Group comparisons

Welch's independent sample t-test revealed no significant differences between groups regarding height, weight, BMI, practice time, or swimming volume (P>0.104; Table 1). The only exception was the age, where the no pain symptoms group was older than the positive group. In addition, age showed large effect size, warranting its inclusion in the subsequent regression model.

After FDR correction, close-to-threshold P-values and large effect sizes were found for several WOSI's subscales (all P=0.061;Fig. 2): physical symptoms domain (d=0.936;Fig. 2A); the sports/recreation/work domain (d=1.017;Fig. 2B); the emotion domain (d=1.026;Fig. 2C); and the total WOSI score (d=0.959;Fig. 2D). All showed a tendency for higher scores for those with positive pain symptoms.

Table 2. Results from the univarate logistic regression analysis for factors associated with shoulder pain symptoms.

			Odds ratio		
Predictor variable	Beta	P-value*	OR	CI95%, lower	CI95%, upper
Age	-1.672	0.012	0.188	0.051	0.698
WOSI, physical	0.893	0.061	2.444	0.960	6.220
WOSI, sports	0.943	0.030	2.569	1.095	6.027
WOSI, emotion	0.901	0.044	2.461	1.025	5.912
WOSI, total	0.892	0.050	2.441	0.999	5.968

The dependent variable was the presence of shoulder pain (coded as 1 if positive, 0 if negative). OR, odds ratio; CI, confidence interval; "physical", WOSI's physical symptoms; "sports", WOSI's sports, recreation and work.

* Non-corrected P-values; FDR corrected P-values were all 0.061.

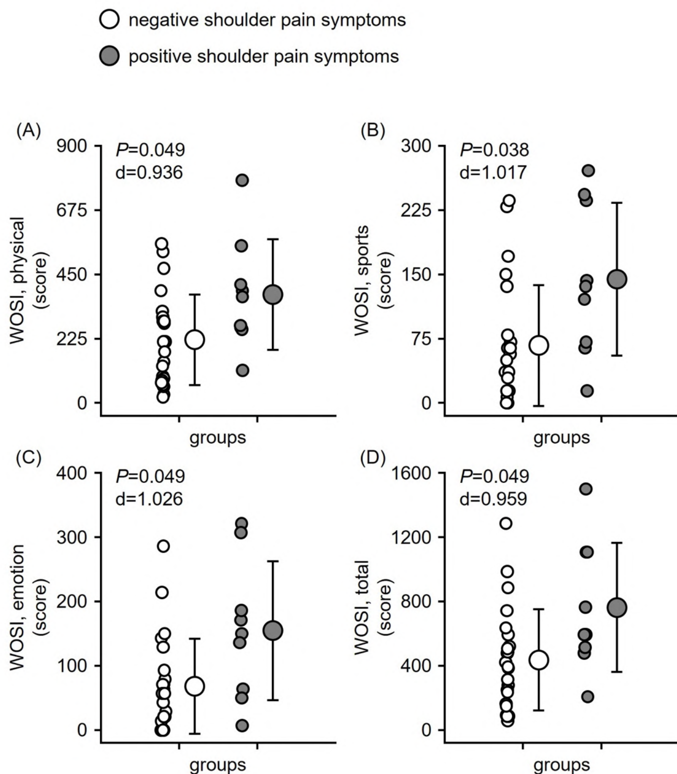

Fig 2. WOSI group analysis. Data are presented as mean (SD) and individual values (small circles) for those with negative (white markers) and positive (gray markers) shoulder pain symptoms. Non-corrected P-value and Cohen's d are shown.

For the UQ-YBT, no significant differences were observed in composite scores or normalized reach distances (P>0.962; Table 1). Similarly, path length measurements showed no significant differences between groups (P>0.348; Table 1). The computed effect sizes were all below d=0.583.

In general, the most pronounced differences between groups were in age and shoulder function (WOSI), while dynamic balance and functional measures were largely similar between groups.

Predictive regression modeling

Logistic regression analysis (Table 2), considering previous shoulder pain as covariate, revealed significant associations between shoulder-related outcomes and demographic and clinical measures. Along with age, the WOSI sports and emotion subscale, together with close-to-threshold effect for WOSI physical function and total score, emerge as significant predictors. Overall, higher disability scores increased the odds of the outcome (shoulder pain symptoms) while increased age reduces its odds.

Discussion

In this prospective study of 32 young swimmers, we investigated clinical and functional factors associated with shoulder pain development. Results showed that athletes reporting shoulder pain after six months already exhibited higher baseline WOSI scores, indicating greater dysfunction and pain perception, while functional measures (UQ-YBT and postural displacements) did not differ significantly between groups. Regression analysis revealed that higher WOSI sub-scores, along with younger age, increased pain risk, suggesting clinical assessments have greater predictive value than functional tests for this outcome in young competitive swimmers.

Our findings align with previous research. Freijen et al.[5] identified five significant predictors of shoulder pain in swimmers: acute-to-chronic workload ratio, competitive level, posterior shoulder muscle endurance, flexion range of motion, and hand entry error. Souza et al.[6] demonstrated that competitive swimming is associated with higher frequency of shoulder pain and rotator cuff injuries, suggesting excessive training load without adequate control contributes to chronic pain development. Finally, Kennedy et al.[7] and Porter et al.[8] highlighted that anatomical and kinesiological variables – such as range of motion, joint laxity, and supraspinatus tendon thickness – are associated with shoulder pain risk.

Our results corroborate previous findings showing that the WOSI is a robust predictor of subjective disability perception,[22,23] with elevated scores correlating with pain presence. Conversely, the UQ-YBT performance was insufficiently sensitive to detect functional deficits related to subclinical pain stages, consistent with studies finding no significant correlation between this test and shoulder injury.[24]

Pain alone does not confirm injury presence. However, its persistence, particularly when accompanied by positive clinical tests, significantly increases musculoskeletal injury risk. According to Hoegh et al.,[25] distinguishing between sport-related pain (absence of measurable tissue damage, typically associated with training adaptations) and sport-related injury (objective clinical signs or imaging findings compatible with structural impairment) is essential. In this context, disabling pain measured by WOSI represents a more advanced stage in the pain-injury continuum,[18] associated with greater dysfunction risk and higher structural injury probability. This distinction, evidenced by higher scores across all WOSI domains (physical symptoms, sports/recreation/work, emotional, and total score) in positive shoulder pain athletes, captures aspects functional tests cannot detect, such as perceived instability, shoulder insecurity, and emotional impact.

Corroborating this view, body height, weight, and swimming volume were not significant predictors of pain presence in the studied sample. This suggests that, in homogeneous groups regarding activity level, anthropometric and load factors alone may not explain pain onset in athletes with a history of instability. It is important to note,

however, that these variables may act as adjusting predictors or even as confounding factors in more complex models and should therefore be considered in the design of future studies.

Limitations

Study limitations include sample size and assessment interval. A larger sample could reveal differences between symptomatic and asymptomatic groups not observed here. Additionally, longer follow-up would increase the probability of pain occurrence, making group comparisons more equivalent. However, observed differences, even after multiple comparison correction, showed strong effect sizes, indicating relevant pain and functionality alterations despite sample size asymmetry. Conversely, longer intervals could increase sample loss due to sport dropout (as occurred with two athletes) or contact loss. Despite limitations, results provide important insights into clinical decision-making and future investigations.

Conclusion

WOSI are useful instruments for identifying athletes at higher risk of developing or exacerbating shoulder complex dysfunction. Elevated scores on these scales are associated with subsequent pain development, even when objective functional tests (UQ-YBT and hand-support postural displacement measures) detect no significant alterations. Our findings corroborate current models positioning perceived disability as a more sensitive risk marker in the pain-injury continuum. Future studies should validate these scales' predictive power and establish clinical cut-off points in sports contexts.

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Conflicts of Interest

The authors report no conflict of interest.

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