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POSTUROGRAPHIC ASSESSMENT OF SHOULDER COMPLEX STABILITY IN SWIMMERS DURING UPPER-QUARTER Y BALANCE TEST: CROSS-SECTIONAL STUDY IN YOUNG ATHLETES, REGARDING HANDEDNESS

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ABSTRACT

Background: The repetitive, high-demand nature of competitive swimming places significant stress on the shoulder joint, frequently leading to pain and instability. These issues-associated with neuromuscular control deficits-underscore the importance of thorough shoulder function assessment to guide rehabilitation interventions.
Objective: The aim of this study was to evaluate the shoulder functional stability during the Upper Quarter Y Balance Test (UQ-YBT), considering handedness as a factor.
Design: Cross-sectional study.
Settings: Rehabilitation department of a sports club.
Participants: Thirty-two (20 female) right-handed young swimming athletes aged 13-16 years old (min-max) participate in the study.
Main Outcome Measure(s): The UQ-YBT was performed over a force platform and was expressed in terms of reaching distances normalized by upper limbs' length, while the postural sway data acquired was expressed in resultant distance path length. A two-way ANOVA was applied to check for main effect and interaction between handedness and UQ-YBT direction. The association between UQ-YBT and path length was assessed through Pearson correlation analysis.
Results: The UQ-YBT performance was progressively lower from medial to inferolateral and superolateral directions ($p < 0.006$), with differences between hands for inferolateral (right > left hand, $p = 0.003$) and medial (left > right hand, $p = 0.005$) directions. Postural sway for the superolateral direction was significantly higher than that observed during the inferolateral and medial directions ($p < 0.001$), and no handedness effect was found ($p > 0.078$). A significant correlation

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was found for UQ-YBT medial direction distances and the medial path length, for both hands (r ranged 0.449-0.576, p <0.013).
Conclusions: The level of challenge presented by the functional test, rather than upper limb lateral specialization, had the greatest influence on shoulder complex stability control.

KEYWORDS
Functional performance, sports medicine, health risk assessment, postural control, biomechanics

INTRODUCTION
Competitive swimming can be defined as a cyclic activity aimed at achieving maximum performance in the shortest possible time to cover a particular distance[1]. In competitive swimming, performance is evaluated in relation to athletic progression, aiming to perform movements in the shortest possible time[1]. Due to the demands of the sport, swimmers are part of the risk group for shoulder injuries, along with athletes from other sports that involve movements with abduction, external and internal rotation above 90 degrees[2]. This situation becomes critical in young athletes, where pain and dysfunction are more prevalent than in other age groups[3].
The demands of swimming on shoulder joint articulation, especially considering the high workload and repetitive movements, can lead to pain and instability[4]. Furthermore, competitive athletes exhibit distinct musculoskeletal characteristics of strength and engage in intense training, both in the aquatic and terrestrial environments, presenting a greater risk for complications[5]. Shoulder pain observed in this context is usually associated with joint hypermobility and deficiencies in sensorimotor control and neuromuscular activation, leading to asymptomatic postural changes that may negatively impact performance, potentially resulting in functional limitations[5]. Moreover, pain, injuries, or dysfunctions in musculoskeletal and neuromuscular structures can lead to impairments in sensorimotor control[6]. In this context, maintaining or recovering the stability of the shoulder complex is an important goal for training and rehabilitation programs.
Stability can be defined as the maintenance of joint alignment and the ability to remain in or return to the original position after a stimulus during functional tasks[7]. The stability of the shoulder complex is achieved by keeping the humeral head within the glenoid cavity, relying on the balance of forces between the static and dynamic components of the joint[8]. These components, particularly the capsular and ligamentous structures, contain neural endings[9], forming part of the sensorimotor system of the shoulder complex[8]. Deficits in the stability of the shoulder complex are associated with joint limitations, a sensation of weakness, and pain during movement[10]. This clinical condition is prevalent in the shoulder joint complex and is generally assessed through the measurement of the joint range of motion or via questionnaires[10]. However, these tools do not provide information about the sensorimotor dynamics involved in movement control and the stability of the shoulder complex.
Posturography, a technique that uses a force platform to assess the application of forces on a rigid surface under static or dynamic conditions, is considered a well-accepted procedure for evaluating postural stability control in the upright position[11,12]. Recently, the force platform has also been used for the assessment of the upper limbs. This technique has been applied and validated in a population of healthy individuals, based on the hypothesis that deficiencies in the sensorimotor control of the shoulder complex (e.g., ligamentous alterations, central inhibitions, neuromuscular control deficits, etc.) will manifest as changes in center of pressure displacements, measured with the individual supported on their hands[13]. Further studies reveal that force platform posturography can identify sensorimotor alterations in both postoperative patients following shoulder joint surgery[14] and those with anterior shoulder instability[13].
However, these studies were limited to investigating the stability of the shoulder complex under static conditions, which reduces the demand for sensorimotor control and may limit the identification of potential alterations in this system. Dynamic tests, such as the Upper Quarter Y Balance Test (UQ-YBT), have been developed to assess the dynamic control of shoulder complex stability. It has been demonstrated that UQ-YBT performance is a predictive factor for shoulder pain and injury[15,16], and it is also capable of distinguishing swimmers with and without scapular dyskinesis[17]. Among physically active young individuals who underwent arthroscopic shoulder stabilization, postoperative improvements in UQ-YBT scores are associated with better patient-reported outcome measures (PROMS)[18,19]. Among the few studies available on young swimming athletes, the results of the UQ-YBT demonstrate test-retest reliability ranging from moderate-to-good to excellent[20] and are influenced by conditioning level[21], sex, and age group (from 10–11 years to 16–17 years[22]). To our knowledge, no studies in this population have utilized force platform posturography for assessment of instability conditions of the shoulder complex.
Based on these issues, we aimed to investigate postural displacements during unimanual support under dynamic conditions, assuming that a higher demand for

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sensorimotor control could highlight differences between task constraints (i.e., movement direction) and individual characteristics (such as lateral dominance) in a group of healthy young athletes. Thus, the objective of this study was to evaluate shoulder complex stability control in young swimming athletes by analyzing center of pressure (COP) displacements during the execution of the Upper Quarter Y Balance Test (UQ-YBT). Additionally, we assessed how laterality potentially influences both functional performance measures (UQ-YBT) and sensorimotor control (COP displacements).

Our hypothesis is that COP displacements reflect UQ-YBT performance, exhibiting lateral asymmetries. Furthermore, we consider that incorporating different movement constraints - such as task restrictions (movement directions) and individual characteristics (lateral dominance) - is essential for an adequate assessment of postural stability control[23]. With our findings, we aim to identify neuromechanical parameters that reflect potential functional alterations in the shoulder complex of swimming athletes, thereby optimizing the evaluation of this population's health status and guiding preventive and rehabilitation strategies.

METHODS

Ethical aspects

This cross-sectional study design was approved by the local Institutional Research Ethics Committee prior to its execution, under the number 30485620.7.0000.5235. After explaining the study's objectives and methods, and before conducting any procedures, all participants' parents or guardians signed a printed informed consent form.

Participants

A convenience sample of 32 athletes, all right-handed, was recruited. A post-hoc analysis, using the effect sizes found in the present study (see Results) and an alpha of 5%, showed that the estimated statistical power was consistently above 80% (G*Power 3.1.9.6, Germany). The characteristics of the sample are presented in *Table 1*. The athletes had an average of seven years of swimming experience, most of them trained six times a week and covered a training distance of 6-9.5 km per week. Of the total number of athletes, 18 (56%) reported sports-related injuries. The athletes were distributed proportionally between sprinters and long-distance swimmers, with the majority practicing the crawl stroke.

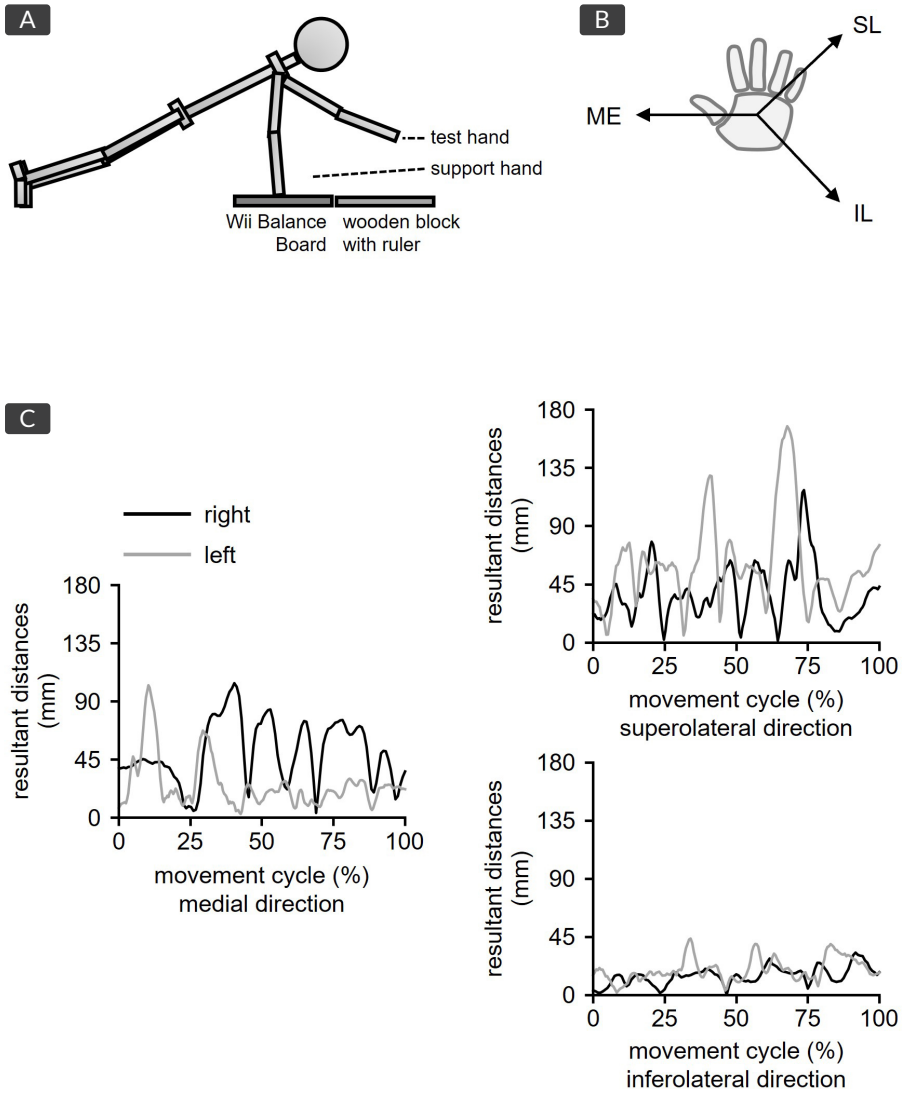


Figure 1. *Illustration of (A) the UQ-YBT procedures and (B) the corresponding directions of the test, showing the position of the supporting and testing hands.*

C) Postural sway expressed as resultant distances for the right hand (black lines) and left hand (gray lines). Data was acquired during UQ-YBT in the medial (left panel), superolateral (upper-right panel), and inferolateral (bottom-right panel) directions. For adequate comparison, the abscissa was adjusted to percentage of movement duration.

Abbreviations: SL, superolateral; ME, medial; IL, inferolateral.

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Sample size (n)	32
Age (years)	14 (13-16)
Height (cm)	168 (157-187)
Weight (kg)	57.9 (44.0-80.0)
BMI (kg/m^2)	20.4 (15.8-23.8)
Sex (*n*, F/M)	20/12
Handedness (*n*, R/L)	32/0
Previous sports-related injury (*n*, Y/N)	18/14
Practice time (years)	7 (3-13)
Swimming (n)	
Sprinter	16
Long distance	15
Half bottom	1
Swimming style (n)	
Crawl	12
Butterfly	8
Breaststroke	6
Backstroke	4
Medley	2

Table 1. *Sample characteristics.*
Data expressed as mean (min-max) or absolute frequency (N).
Abbreviations: F/M, female/male; R/L, right/left; Y/N, yes/no.

Upper Quarter Y Balance test

Before the test, the athletes were instructed and received a demonstration from the evaluator on the correct procedure. A familiarization period-which included a 20-second recording of a bimanual stance, a 20-second recording of a unimanual stance for each hand, and a few UQ-YBT practice trials-was allowed to ensure task comprehension and reduce potential learning effects, with no errors or difficulties observed. Data collection was conducted in a single session, always at the same time of day following swimming training. To maintain standardization, a single evaluator performed all tests.

Participants were instructed to perform the UQ-YBT on the force platform. They were positioned in a push-up posture, supported randomly by either their left or right hand. Participants were required to maintain their shoulders and wrists flexed at approximately 90 degrees, with elbows fully extended and the supporting hand in contact with the force platform. The head was kept in a neutral position, while the trunk and lower limbs remained fully extended, supported by their feet positioned apart in alignment with the hip joint *(Fig. 1A)*. Following the familiarization period, the athletes were instructed to reach as far as possible in one of three directions *(Fig. 1B)* and then return to the initial position[24]. Each trial consisted of three reaching movements, lasting 20-seconds, and was followed by a 30-second rest period before proceeding to a trial in a different direction. A wooden ruler was placed near the platform in the corresponding direction to record the distances achieved. We used this approach as it closely resembles the standard YBT instrument and provides a practical solution for clinical and sports settings. For each trial, the distance reached by the "test" hand and the postural sway of the supported hand were recorded. UQ-YBT performance was expressed as normalized percentage of the distance reached relative to each athlete's upper limb length. Upper limbs lengths were measured in centimeters, from the spinous process of the 7th cervical vertebra to the tip of the middle finger[22].

Postural sway acquisition and processing

The coordinates of the center of pressure (COP) were acquired using a Wii Balance Board (WBB, Nintendo Co Ltd, Japan) force platform. The data were transmitted to a laptop via Bluetooth and recorded at a 30 Hz sampling rate in a custom program written in LabView (National Instruments, USA). The signals were stored for offline analysis. The WBB was calibrated in accordance with the manufacturer's recommendations.

The following data processing was performed in Python 3.11.7 environment. Original signals were resampled to 100 Hz using the Sliding Window Average with Relevance Interval Interpolation (SWARII) algorithm[25]. Center-of-pressure coordinates in the anteroposterior and mediolateral directions were transformed into a single resultant distance (RD) time series[26] *(Fig. 1C)*. From RD, the path length (PL, the summed distances between coordinates' consecutive points[26], in millimeters) was computed and used to express the magnitude of postural sway.

Lateral Symmetry Index

Handedness effect was further explored through the calculation of the lateral symmetry index (LSI, as percentage), using equation 1:

$$\mathrm{LSI} = \frac{(\mathrm{variable.right} - \mathrm{variable.left})}{(\mathrm{variable.right} + \mathrm{variable.left})} \times 100$$

with "variable" referring to reaching distances or postural sway, for each UQ-YBT direction, and "right" and "left" indicating the hand used to perform the task. A positive (negative) LSI corresponds to increases in variables toward the right (left).

Statistical analysis

Sex and the presence of previous shoulder pain were excluded from the final model as they did not show significant effects in preliminary analyses. Since most

(75%) of the variables showed a normal distribution (Shapiro-Wilk's p >0.185), a parametric approach was deemed appropriate. The statistical threshold was set at 5%. All analyses were performed using the JASP 0.18.3 environment (The JASP Team, 2024, Netherlands).

First, two-way repeated measures ANOVA were applied to examine the interaction and main effects for handedness (left vs. right) and UQ-YBT directions (superolateral, medial, and inferolateral) on both UQ-YBT performance and postural sway measures. Significant main effects were further explored using Holm's post-hoc test to examine the main effect of directions, and the paired t-tests to examine the significant handedness*directions interaction. Holm's post-hoc test was used because it provides strong control of the Family-Wise Error Rate while being more powerful and less conservative than the classic Bonferroni correction[27]. Partial eta squared (ηp^2) and Cohen's d were used to estimate the effect sizes of the ANOVA and t-tests, respectively. To further explore the handedness effect, the LSIs were compared with zero-value reference using a one-sample t-test. Finally, the level of association between UQ-YBT performance and postural sway descriptors was computed using the Pearson correlation coefficient.

RESULTS

UQ-YBT performance

All participants completed the tasks without interruption and none reported pain, difficulty in maintaining the position, presented tremors or gave up on completing the proposed activity within the determined timeframe.

Analysis of the UQ-YBT performance revealed a significant interaction handedness*directions ($p < 0.001$, $\eta p^2 = 0.263$), and a significant main effect for directions ($p < 0.001$, $\eta p^2 = 0.415$) but not for handedness ($p = 0.563$, $\eta p^2 = 0.013$). Post-hoc comparisons showed that all UQ-YBT directions differed significantly from each other (all Holm's $p < 0.006$), with the shortest reaching distances in the superolateral direction, followed by the inferolateral and then the medial directions *(Fig. 2A)*. Furthermore, significant differences were found in UQ-YBT performance between the left and right hands for the inferolateral (right higher than left hand; $p = 0.003$, $d = 0.573$) and medial (left higher than right hand; $p = 0.005$, $d = -0.557$) directions, but not for the superolateral direction ($p = 0.949$, $d = 0.012$; *Fig. 2A*). LSI analyses corroborate these results, based on the deviation from zero for the inferolateral (mean ± SD; 1.571 ± 2.597%; $p = 0.002$) and medial (-0.939 ± 1.686%; $p = 0.005$) directions indices, but not for the superolateral index (-0.063 ± 2.764%; $p = 0.901$).

Postural sway during UQ-YBT test

The analyses of the postural sway under the supporting hand during the UQ-YBT tests, expressed as RD_{PL}, showed no significant handedness*directions interaction or main effect for handedness (both $p > 0.078$), but revealed a significant main effect for directions ($p < 0.001$, $\eta p^2 = 0.714$). Post-hoc analyses showed that postural sway in the superolateral direction was significantly higher than that observed in the inferolateral and medial directions (post-hoc $p < 0.001$; *Fig. 2B*). The lack of a handedness effect was confirmed by the non-significant results for the superolateral (-0.065 ± 12.234%, $p = 0.978$) and inferolateral (4.381 ± 16.381%; $p = 0.168$) directions' indices compared with zero. However, the index for the medial direction (6.515 ± 16.861%) approached significance ($p = 0.051$), suggesting a trend toward higher RD_{PL} in right versus left hand for this direction *(Fig. 2B)*.

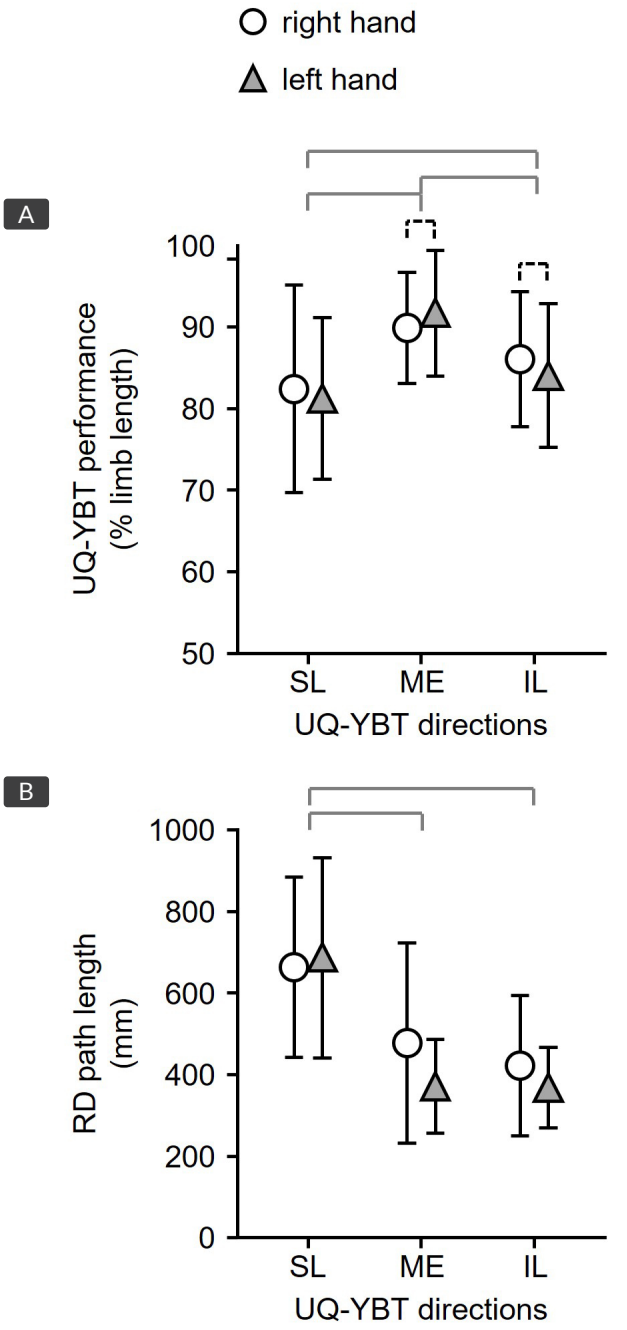


Figure 2. *Mean ± SD of (A) UQ-YBT performance and (B) resultant distance (RD) path length for the right (white circles) and left (gray triangles) hands. Dotted lines indicate differences between hands. Continuous gray lines indicate differences between directions. Abbreviations: SL, superolateral; ME, medial; IL, inferolateral.*

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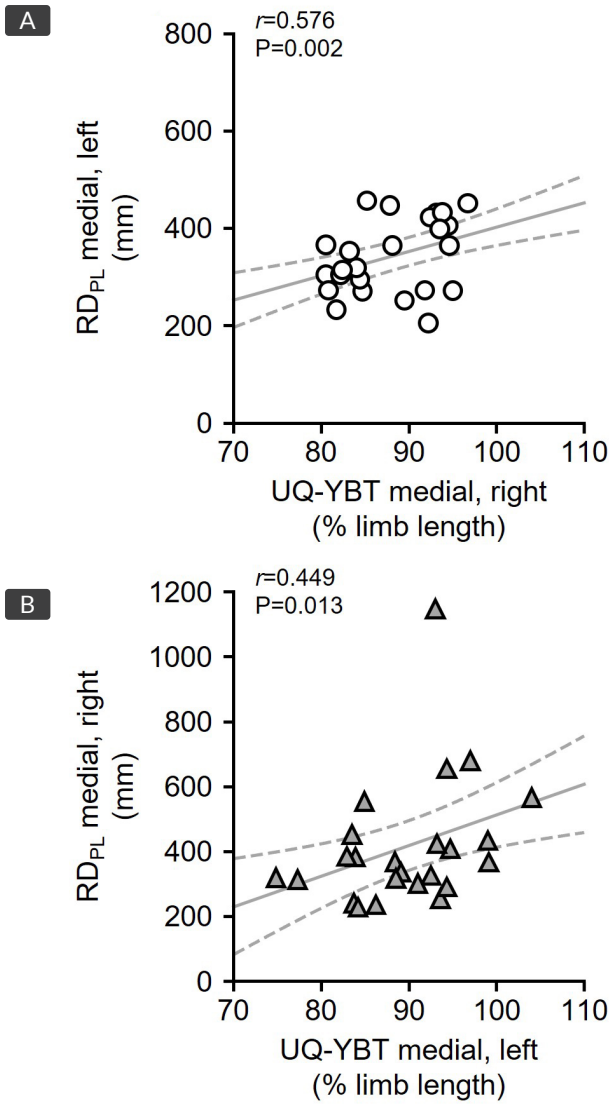


Figure 3. Scatterplot of UQ-YBT performance versus resultant distance path length (RD_{PL}) in the medial direction. A) Right hand; B) Left hand. Pearson correlation coefficient (r), the corresponding P-value, and the estimated regression line (continuous gray line), along with the 95% confidence interval (dotted gray lines), are also shown.

Association between YBT-UQ performance and postural sway

The association between test performance and the corresponding postural sway was made through correlation analysis between contralateral hands; for example, right hand YBT-UQ distance achieved versus left hand RD path length. There was a significant, positive, and moderate correlation between UQ-YBT performance and postural sway only for the medial direction *(Table 2)*. This effect was observed for both hands *(Fig 3A and B)*.

DISCUSSION

Our study evaluated the stability control of the shoulder complex using posturography in dynamic conditions, namely the UQ-YBT. Our hypothesis is that posturography in dynamic conditions reflects neuromechanical characteristics of shoulder stability control, such as task direction and lateral dominance. The results show that, while task direction influences both UQ-YBT performance and postural position, lateral dominance marginally affects UQ-YBT performance, but not posturographic results. Furthermore, we observed that, for the medial direction, the highest performance in the UQ-YBT is positively associated with postural displacements. It seems that, in the dynamic conditions evaluated, shoulder stability control is determined more by task constraints than by individual characteristics.

UQ-YBT performance

Few studies have investigated UQ-YBT performance in the population of children and adolescent athletes. Borms and Cools[28] observed significant differences between athletes from different sports and between sexes. Among the different age groups investigated, the youngest group (18-25 years) showed UQ-YBT performance ranging from 96-104% of upper limb length in the medial direction (highest performance) to 63-96% in the superolateral direction (lowest performance[28]). The studies by Schwiertz et al.[20,21], conducted on adolescents aged 12-17 years, also found higher performance values in the medial direction (around 80%) and lower values in the superolateral direction (60%). In these studies, the authors did not find significant differences between sexes or, more importantly, between upper limbs. However, they did find differences between young athletes and those who did not engage in physical activity, with a 75-90% chance of distinguishing young athletes from sedentary individuals[21]. In a more comprehensive study, Schwiertz et al.[22] observed differences between age groups (with younger individuals showing lower performance), depending on task direction, as well as between sexes in the 12-13 age group and older (with males generally performing better than females). Finally, Butler et al.[29], evaluating adolescent athletes, identified the same directional effect observed in other

	r (95% CI)	p value
UQ-YBT right vs. RDPL left		
Inferolateral	-0.058 (-0.429, 0.329)	0.773
Medial	0.576 (0.243, 0.788)	0.002
Superolateral	-0.025 (-0.388, 0.345)	0.897
UQ-YBT left vs. RDPL right		
Inferolateral	0.219 (-0.168, 0.548)	0.262
Medial	0.449 (0.105, 0.696)	0.013
Superolateral	0.056 (-0.331, 0.427)	0.781

Table 2. Association between UQ-YBT performance and postural sway for each direction and hand.
r, Pearson's correlation coefficient. 95% CI, confidence interval.

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studies (higher performance in the medial direction) but did not find any effect of sex or lateral dominance.

The data obtained on young swimmers in the present study partially converges with findings observed in different age groups and overhead sports. In the previously mentioned work by Borms and Cools[28], UQ-YBT performance was higher in the medial direction than in the inferolateral and superolateral directions, which aligns with our results. They also reported that performance in the medial direction was higher in volleyball players compared to handball players, while superolateral performance was greater in the youngest athletes (18-25 years) than in the oldest cohort (26-50 years). However, a contrasting result was found by Tooth et al.[30] who assessed athletes from various sports aged 18 to 35 years. Their study indicated that overall UQ-YBT performance increased from the inferolateral to the superolateral and medial directions. Furthermore, they found no significant differences between sports and no age influence. In summary, despite minor variations, UQ-YBT performance in the medial direction appears to outperform both the superolateral and inferolateral directions across different sports and ages. The specific effects of sport type and athlete age remain a subject of debate, as no clear pattern has yet emerged from the available literature.

In general, the literature data support the findings of the present study regarding the effect of task direction on test performance. However, the dominance effect observed in the medial and inferolateral directions in the present study (although minimal) has not been reported yet. Additionally, the values obtained in the superolateral direction are slightly higher than those reported in other studies. These discrepancies may be due to the specificity of the population investigated: while most studies assess students or local-level athletes, the present study evaluated high-performance athletes engaged in national competitions. Butler et al.[29] also assessed national-level swimming athletes, but the influence of lateral dominance was not evaluated in that study. As shown by Schwiertz et al.[21], sports practice affects UQ-YBT performance, and the level of competition of the athletes may also influence this measure.

Postural sway

The available studies on the assessment of shoulder complex stability control using a force platform have been conducted under static conditions (i.e., the participant supported without displacing any part of the body). In addition to the study by Edouard et al.[31], which evaluated the reliability of the test on the force platform, other studies have investigated the posturographic responses of patients with recurrent shoulder instability[13] and after different surgical procedures aimed at shoulder stabilization[14]. In general, posturography showed greater displacement on the unstable side compared to the unaffected side (a difference of about 26%[13]) and greater displacements on the operated side (103-120 cm) compared to the healthy side (98-108 cm[14]).

Our hypothesis was partially confirmed, as differences in postural displacement were observed between directions but not between upper limbs *(Fig. 3B)*. Specifically, greater postural displacement was observed during the UQ-YBT in the superolateral direction (around 600 mm), with no significant differences between the medial and inferolateral directions (both varying around 400 mm). There was also an association between postural displacement and UQ-YBT performance in the medial direction, where greater displacement corresponded to greater reach in this direction for both hands *(Fig. 3)*. From this set of results, two findings stand out: (A) the greatest displacement was observed in the direction with the lowest UQ-YBT performance (superolateral); (B) the significant association between postural displacement and performance was found in the direction with the greatest reach distances (medial).

Although the superolateral direction is the one with the shortest distances reached *(Fig. 2A)*, it may be the direction with the highest demand for postural stability of the

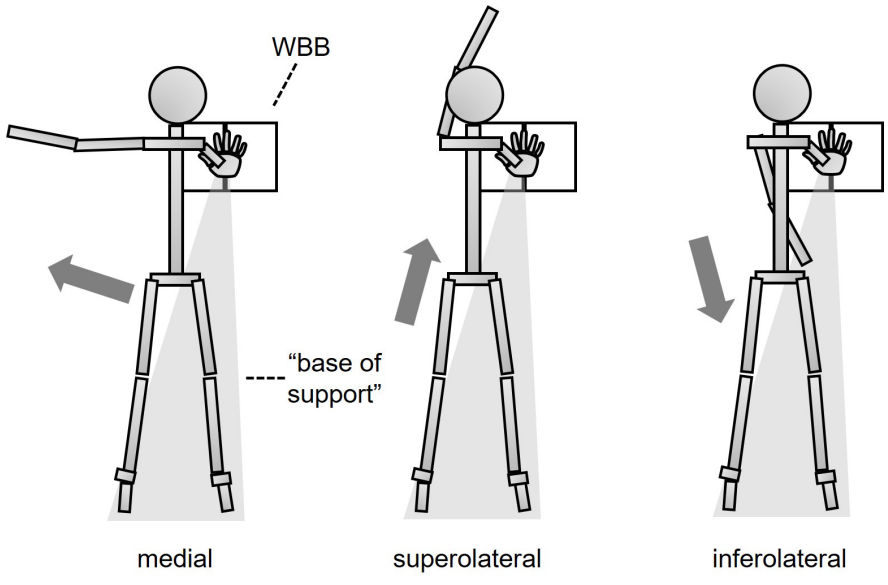


Figure 4. *Schematic representation of the biomechanical features of the UQ-YBT over the force platform. The base of support during the test is conceptualized as a triangle, with the feet forming the base of the triangle and the supporting hand representing the apex. The presumed displacement of the center of mass in each task is indicated by the gray arrows. See the text for further details.*

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shoulder complex. Let us imagine the base of support during the test as a triangle, where the base consists of the feet and the apex is the supporting hand *(Fig. 4)*. In this case, reaching in the superolateral direction involves projecting the hand beyond the single support point of the base (i.e., the apex of the triangle), resulting in greater distribution of body weight at that point (*Fig. 4*, middle panel). Conversely, in the medial and inferolateral directions, although the hand is also projected "outside" the base of support, body weight can be more easily distributed among all support points (the base and apex of the triangle; *Fig. 4*, left and right panels), reducing the control demand and resulting in smaller postural displacements in the supporting hand. Similarly, we could consider changes in body weight distribution in the upright position when using crutches - for example, the fact that the center of pressure of the feet shifts toward the side where the crutch is used[32], which, in hemiplegic patients, leads to a reduction in body weight distribution on the unaffected leg[33]. Thus, the different directions of the UQ-YBT (i.e., the intrinsic characteristics of the task) require different body weight distribution patterns, thereby affecting shoulder stability control and the postural displacements observed in the supporting hand.

In the medial direction of the UQ-YBT, we found a positive association between performance and postural displacement. It seems that, in this task, shoulder stability control prioritizes the movement of the reaching hand over maintaining shoulder and body stability. Returning to the explanation of the triangular support base, we can assume that the displacement of the hand in the medial direction, "outside" the body's vertical axis, would not cause significant changes in weight distribution among the support points, allowing the supporting hand to assist upper limb mobility rather than ensuring body stability. Conversely, changes in body orientation along the longitudinal axis, as seen in the superolateral and inferolateral reaching directions, would promote weight redistribution among the support points, thereby engaging sensorimotor control mechanisms to maintain body stability.

This interpretation supports the idea of postural adjustments depending on task constraints (e.g., see[23]). Within this conceptual framework, variations in postural displacement, in terms of magnitude and direction, cannot be classified as "good" or "bad" in relation to greater or lesser body stability. Instead, they should be understood in a context where these displacements adapt to the interrelated demands of the task, environment, and individual. Examples of this type of "demand-driven adjustment" in postural control can be seen in individuals with visual impairment[34], who exhibit postural displacements similar to those with normal vision in certain body postures but not in others. Additionally, some studies have shown that postural displacements can exhibit exploratory behavior under specific conditions, prioritizing an increase in sensory input rather than body stability[35,36].

Thus, we understand that the postural adjustments observed in unimanual support during the UQ-YBT adapted specifically to the demands of the presented tasks, with minimal influence from individual factors, as assessed by lateral dominance.

Study limitations

This study has limitations that should be acknowledged: the convenience sample of right-handed athletes limits the generalizability of the findings to left-handed individuals and other sports; testing was conducted after swimming training, so the potential influence of residual fatigue cannot be excluded; furthermore, the use of an adapted wooden ruler instead of the commercial YBT kit may introduce additional variability. Nevertheless, some considerations mitigate these concerns: despite reduced generalizability, our results align with those reported for young swimmers and partially converge with findings in other sports and age groups; although fatigue may be present, all athletes were similarly exposed, and the repeated-measures design helps control for its potential confounding effect; finally, the wooden marker offered a practical way to replicate standard clinical testing and enhance the protocol's applicability in real-world sports settings.

CONCLUSIONS

Young swimming athletes exhibit a dissociation between upper limb functional test performance and the postural displacements recorded in the supporting hand: while the former is influenced by task constraints and individual characteristics, the latter is affected solely by task-related factors. Shoulder stability control, as assessed in this study, is driven by task demands, prioritizing either mobility or stability depending on the movement's objective. Future studies should investigate the influence of sensorimotor dysfunctions in the shoulder on these adjustments, which would be relevant both for functional diagnosis and for developing prevention programs for pain and musculoskeletal injuries.

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