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original research

Sex Differences in Dynamic Closed Kinetic Chain Upper Quarter Function in Collegiate Swimmers

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Context: Upper quarter injuries have a higher incidence in female swimmers; however, to date, there are few ways to assess the basic functional ability of this region. The upper quarter Y balance test (YBT-UQ) may assist in this process because it was developed to provide a fundamental assessment of dynamic upper quarter ability at the limit of stability.

Objective: To examine how sex affects performance on the YBT-UQ in swimmers.

Design: Cohort study.

Patients or Other Participants: Forty-three male and 54 female National Collegiate Athletic Association Division I college swimmers were recruited preseason.

Main Outcome Measure(s): We measured YBT-UQ performance for the left and right limbs in the medial, inferolateral, and superolateral directions. The maximum score for each direction was normalized to upper extremity length. The average of the greatest normalized reach scores in each reach direction was used to develop a composite score (average distance in 3 directions/limb length [LL] × 100). To examine reach symmetry between sexes, the difference in centimeters between the left and right sides was calculated for each reach direction prior to normalization. Statistical analysis was conducted using an independent-samples *t* test ($P < .05$).

Results: Average scores in the medial (women: 92.5 ± 7.4%LL, men: 100.0 ± 8.7%LL; $P < .01$) and inferolateral (women: 85.6 ± 10.3%LL, men: 89.8 ± 10.8%LL; $P = .05$) directions and composite score (women: 83.4 ± 8.3%LL, men: 88.3 ± 8.9%LL; $P < .01$) were higher in men than in women. No differences were observed for reach symmetry in any direction.

Conclusions: Performance on several YBT-UQ indices was worse for female than male collegiate swimmers. These results may have implications for the use of preseason and return-to-sport testing in swimmers as a measurement of upper quarter function and symmetry.

Key Words: Y-Balance test, core stability, shoulder function, injury risk

Key Points

- Female collegiate swimmers exhibited worse performance than their male counterparts on the upper quarter Y-balance test in the medial and inferolateral directions as well as in the average overall score.
- No sex differences existed for reach symmetry for any of the reach directions.
- The worse performance in women may be associated with shoulder and core stability limitations, which may explain the increased incidence of upper quarter injuries in female swimmers.

Upper quarter injuries are the most common injuries sustained by collegiate swimmers.[1,2] More specifically, female swimmers have an increased risk of upper quarter injuries of the shoulder and back/neck compared with their male counterparts.[1,2] Sallis et al[3] found that female swimmers sustained 21.05 and 8.19 injuries/100 participant years, whereas male swimmers experienced 6.55 and 1.45 injuries/100 participant years for the shoulder and back/neck, respectively. These injuries are disabling, often contribute to decreased performance and missed practices and competitions, and may require surgery. A number of extrinsic and intrinsic variables have been shown to contribute to the increased risk of upper quarter injuries, regardless of sex.[2,4–11] Extrinsic factors include rigorous training exposure focusing on shoulder-intensive movements, reduced cross-training or participation in other sports, prior injury, and age. Intrinsic risk factors include laxity of the capsuloligamentous structures, decreased core and scapular muscle endurance, and scapulothoracic and glenohumeral muscular imbalance; screening tools to assess these components and eventually minimize the role these factors play in overall injury risk for swimmers may be helpful. Currently, insufficient data exist for upper quarter functional testing in swimmers. Additional upper quarter functional testing may further explain the possible sex-related characteristics associated with injury disparity. Effective and functional upper quarter testing could be used to help develop offseason and dry-land training programs focused on performance enhancement and injury prevention.[12,13]

Swimming requires a significant amount of upper body and core strength, endurance,[11,14] and shoulder mobility and stability.[5] Although a number of tests have been designed to assess upper quarter function, few tests assess upper quarter

Table. Descriptive Statistics on the Comparative Groups of Collegiate Swimmers

Characteristic	Men (n = 43)	Women (n = 54)
Age, y	19.3 ± 1.2	19.1 ± 0.7
Height, m	1.77 ± 0.05	1.69 ± 0.05
Limb length, m	0.90 ± 0.05	0.84 ± 0.05
Mass, kg	73.2 ± 11.0	64.8 ± 5.3

stability at the limit of closed chain stability,[15–18] which has been associated with performance enhancement and injury prevention in swimmers.[12,13] The upper quarter Y balance test (YBT-UQ) can be conducted in the field setting with minimal equipment and examines the unilateral performance of the upper quarter at the end range of the athlete's ability to maintain stability.[15–18] The YBT-UQ challenges the core and upper quarter strength, stability, and mobility that are required for the performance demands of swimming.[13,16,18] The YBT-UQ is a reliable functional test,[16,18] demonstrating a fair to moderate association with several tests that measure core stability (push-up and lateral side bend endurance, range, 0.38–0.45) and upper extremity function (closed kinetic chain upper extremity stability test, range, 0.43–0.49).[18] Current research supports the notion that YBT-UQ performance is not affected by competition level,[19] sex, or limb dominance in active adults[18] and healthy college students.[16] However, performance on the YBT-UQ has yet to be assessed in swimmers, who have different upper quarter demands than previously tested populations.

Previous authors[3] have shown that female swimmers are at increased risk for injury to the upper quarter compared with their male counterparts. Reasons for this discrepancy are unknown. Basic tests of upper extremity function in athletes, particularly those in sports with significant upper quarter demands, may allow us to identify movement limitations that can be addressed to improve the athlete's endurance. Such tests may also be beneficial in assessing progress in dry-land training programs aimed at improving swimming performance.[13] Given the current gaps in the literature, it is beneficial to examine YBT-UQ performance in male and female swimmers to determine if sex differences exist in performance. Based on previous research, we expected no sex difference on the YBT-UQ.[16,18]

METHODS

Participants

A total of 43 male and 54 female National Collegiate Athletic Association Division 1 collegiate swimmers were recruited for the study before their swimming season. We conducted an a priori power analysis ($\alpha = .05$, $\beta = .20$); for a meaningful effect size difference of 0.50, 35 athletes needed to be recruited for each group to establish statistical power. Thus, the size of the sample collected suggests that statistical power was ample to observe significant differences. Sex differences across anthropometric measures and participant characteristics were apparent (Table). As expected, the male collegiate swimmers had longer arm lengths, were taller, and had more mass than the female collegiate swimmers. All athletes who reported pain, were currently injured or under care of the sports medicine team, or had sustained an injury in the past 6 months were excluded from the study. All other athletes who were currently participating in full team activities were enrolled. The research protocol was approved by the institutional review board before data collection. We obtained written informed consent from each athlete before the study.

Procedures

We measured the upper quarter limb length (LL) of each athlete standing with feet together, shoulders in a 90° abducted position, the elbows extended, and wrists and hands in neutral. A cloth tape measure was used to determine the distance in centimeters from the spinous process of the seventh cervical vertebrae to the tip of the right middle finger.

The YBT-UQ tests an individual's ability to execute a unilateral task while maintaining 3 points of contact (1 hand and 2 feet) with the ground in a plank position and feet shoulder-width apart (Figure 1). A Y-Balance Test Kit (Move2Perform, Evansville, IN) and the YBT-UQ protocol were used during testing.[16] This protocol has been established as reliable across raters and across days (6). Participants were barefoot. The *starting position* was defined as the feet placed shoulder-width apart in a push-up position with the tested hand on the stance platform and the thumb adducted and aligned behind the red line. The reach hand was positioned on top of the reach box shoulder width from the stance hand. The test consisted of 3 trials. Each trial required the athlete to reach in 3 directions, (medial, inferolateral, and superolateral) in this standardized order, with the free hand pushing the box by contacting only the side of the box in the area of the red tape before returning to the starting position in a controlled manner (Figure 1). For a trial to be completed successfully, the following criteria had to be met: (1) 3 points of contact were maintained between the floor and feet and between the stance hand and stance platform at all times, (2) the athlete did not use momentum to move the reach box (ie, push the box so that it was in motion when contact between the hand and box was lost), (3) the athlete did not use the top of the reach box or any testing equipment to stabilize the body, (4) the athlete did not let the reach hand touch the ground during the trial, and (5) the athlete returned the reach hand to the starting position at the end of the trial. If any of the criteria were not met, the trial was discarded, the athlete was allowed to rest, and the trial was repeated until 3 successful trials in each direction were completed. To familiarize the athlete with the test, the examiner explained and demonstrated the procedure. The athlete then completed 2 practice trials on the right side, followed by 2 practice trials on the left side. The tested side was named for the stance, support side. After all of the practice trials were completed for both sides, 3 performance trials were completed for the right side followed by 3 performance trials for the left side. The examiner asked each athlete if pain was present during any of the practice or performance trials.

Each reach distance was measured to the nearest 0.5-cm increment. The maximum score for each reach direction was then used for calculations to represent the end range of each athlete's performance. To compare the reach distance between sexes, the maximum score was normalized to the

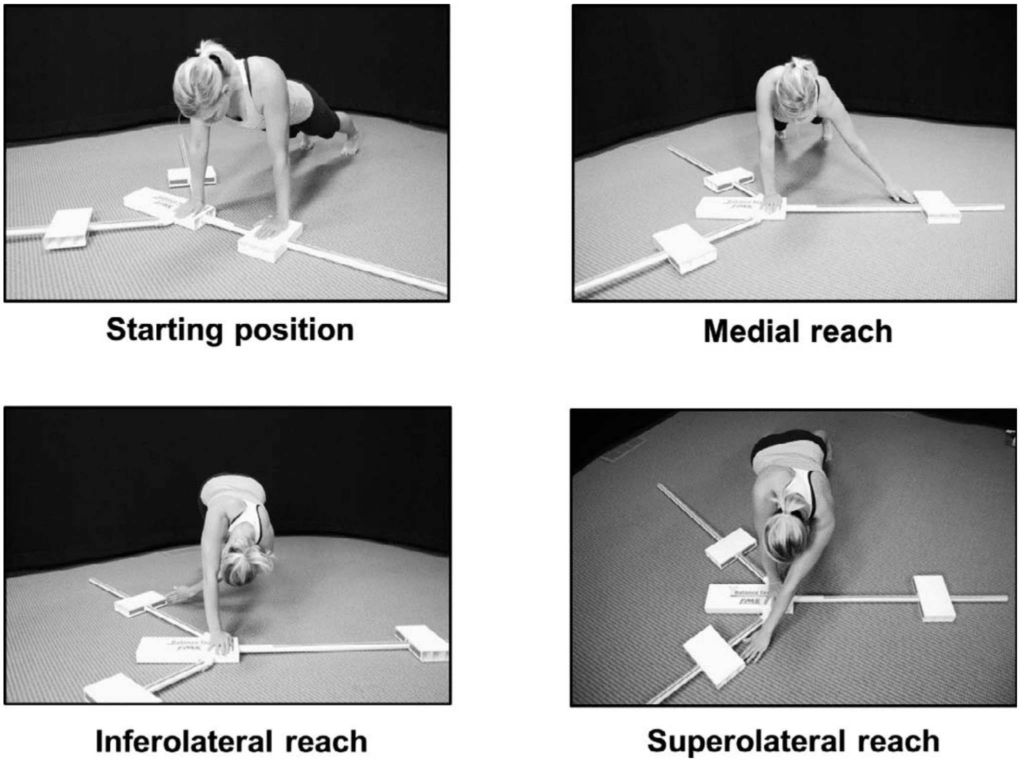

Figure 1. Description of the starting position and different reach directions of the upper quarter Y balance test.

individual's limb length (calculated as the percentage of limb length). The normalized values for the left and right sides were then averaged for each direction. We compared the mean values for each reach direction and the composite score (the average of the normalized values) across all directions between sexes. Reach asymmetry was also compared between sexes. The absolute value of the difference between the maximum reach on the left and right sides for each athlete was determined for each reach direction. The mean absolute value for each direction was compared between sexes. Finally, the absolute value differences for all 3 directions were summed together and compared between sexes.

Statistical Analyses

We analyzed the sex differences using SPSS (version 17.0; SPSS Inc, Chicago, IL). Sex differences in the YBT-UQ normalized reach distance (%LL) for each direction, composite score for the normalized reach, reach asymmetry (cm) for each direction, and asymmetry sum across all directions were analyzed using an independent-samples t test. All statistically significant differences were identified at $P < .05$. Effect size indices (ESIs) were also calculated for all variables of interest as the mean for the men minus the mean for the women divided by the pooled standard deviation.

RESULTS

Male swimmers exhibited greater dynamic closed chain upper quarter function on the YBT-UQ for independent reach directions as well as for the composite score (Figure 2). Specifically, male swimmers had greater medial (mean ± standard deviation; men: 100 ± 8.8%LL; women: 92.5 ± 8.1%LL; ESI = 0.89) and inferolateral reach (men: 89.8 ± 10.8; women: 85.6 ± 10.3; ESI = 0.40), as well as composite score (men: 88.3 ± 8.9; women: 83.4 ± 8.3; ESI: 0.57). No differences were observed for the superolateral reach (male: 74.9 ± 9.7; female: 72.1 ± 11.2; ESI: 0.27).

In contrast to the findings for the independent reach directions and composite score, we noted no differences for reach asymmetry (Figure 3). Reach asymmetry was smallest for the medial reach direction (men: 3.3 ± 2.6; women: 3.4 ± 2.8; ESI: 0.04), followed by the inferolateral

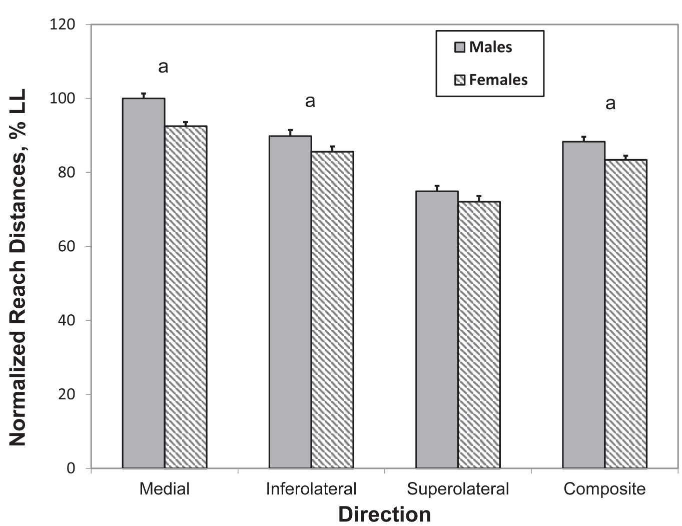

Figure 2. Differences between male and female collegiate swimmers for normalized reach across the independent directions of the upper quarter Y balance test as well as for the composite score. [a] Indicates significance ($P < .05$). Abbreviation: LL, limb length.

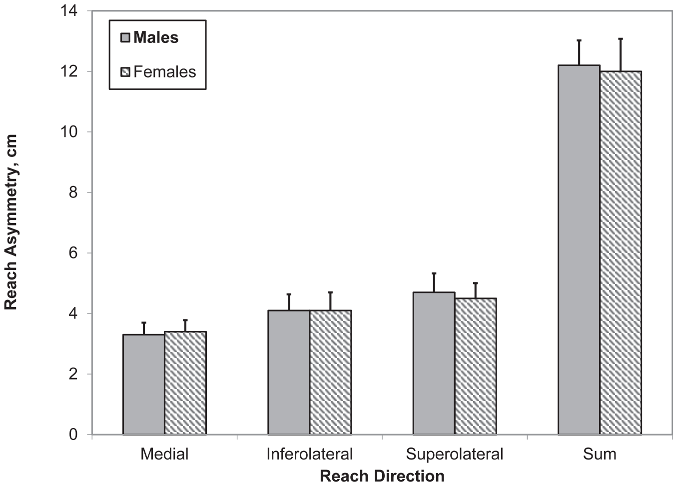

Figure 3. Differences between male and female collegiate swimmers' reach asymmetry score across all independent reach directions of the upper quarter Y balance test and summed asymmetry scores.

(men: 4.1 ± 3.5; women: 4.1 ± 4.4; ESI: 0.0) and superolateral (men: 4.7 ± 4.1; women: 4.5 ± 3.7; ESI: 0.05) reach directions. The sum of the reach asymmetry scores was 12.2 ± 5.4 for the male collegiate swimmers and 12.0 ± 7.9 for the female collegiate swimmers (ESI: 0.03).

DISCUSSION

Female swimmers have a higher injury rate than their male counterparts, particularly in the upper quarter.[1,2] Few functional tests of dynamic closed kinetic chain upper quarter function can be used expediently in a field setting to potentially explain underlying mechanisms for the elevated injury rate in female swimmers. Previous investigators[16,18] have established the YBT-UQ as a reliable test that can be administered successfully by different raters and across different days. Current research suggests that no sex or bilateral differences exist in YBT-UQ performance in the general population.[16,18] However, we are aware of no research conducted in swimmers, in whom a sex discrepancy in upper quarter injuries has been established.

We observed sex differences in dynamic closed kinetic chain upper quarter function in the collegiate swimmers. This finding was contrary to our study hypothesis of no sex difference based on prior studies[16,18] of the YBT-UQ in the general population. Unfortunately, no other authors have examined sex differences on other upper extremity functional tests, including the closed kinetic chain upper extremity stability test and the 1-armed hop test.[15,17] Therefore, we cannot directly compare our results against other studies of upper quarter functional tests. The reach distances and composite scores we calculated are similar to previously reported values for the YBT-UQ.[16,18]

Previous researchers[18] have suggested that performances on core stability tests (push-ups and lateral trunk endurance test, range, 0.38–0.45) are correlated with performance on the YBT-LQ, which may provide a rationale for the differences in performance. Although we did not directly test this, worse performance in core stability tests has been observed in female athletes.[20,21] Worse performance on the YBT-UQ may be attributed to less core stability in our female swimmers in addition to the typically associated construct of shoulder stability (correlation between the closed kinetic chain upper extremity stability test and YBT-UQ: range, 0.43–0.49 per Westrick et al).[18] Of the 3 reach directions, the medial and inferolateral reaches appear to require the greatest trunk mobility in a stabilized posture, which may explain why females exhibited the greatest performance deficits in these 2 reach directions. Thus, although the test clearly assesses shoulder complex stability, it appears that the role of core stability in this test cannot be overlooked and is relevant to focus on when attempting to improve performance on the YBT-UQ. The YBT-UQ may serve as a continuous biomarker of progression for core and shoulder stability training programs.

Electromyographic analysis and local muscle strength testing of the trunk and shoulder complex musculature during the YBT-UQ would be beneficial for a greater understanding of the different muscular demands. This additional study may assist us in developing effective training programs to resolve deficits observed on the YBT-UQ, particularly when the deficits are in specific reach directions.

Our participants performed symmetrically between the left and right sides during the YBT-UQ, which supported our initial hypothesis. Symmetric upper quarter performance has previously been observed during the 1-armed hop test in collegiate male athletes.[15] However, neither we nor Falsone et al included athletes whose sports promote upper quarter asymmetry.[15] These findings may differ in athletes whose sports have a strong unilateral component (eg, baseball and softball). Wilk et al[22] suggested that asymmetry in external rotation of the glenohumeral joint was associated with an elevated risk of injury, although the confidence interval was not significant. Thus, asymmetry has not been seen on YBT-UQ performance in asymptomatic populations, but it may be a relevant factor in future studies examining the injury risk validity of the test. Based on this initial work, we would consider swimmers observed to have large asymmetries atypical; strength and conditioning programs that normalize these asymmetries may help to enhance performance and prevent injury.

Future investigators should assess the prospective injury validity of the YBT-UQ and whether test performance is modifiable in a way that reduces injury risk. It will also be beneficial to examine which common muscle-strength deficits correlate with poor performance on the YBT-UQ in order to develop effective retraining programs aimed at improving test performance. In addition, correlating the relationship between YBT-UQ and athletic performance would allow us to understand the utility of this biomarker in developing off-season training programs and goals.

As does any study, ours had limitations. First, we did not collect long-term injury histories from our swimmers, all of whom were from a single institution. This information might have been helpful in identifying specific performance deficits in athletes with a previous injury. Replicating this study across multiple institutions will be beneficial in improving the external validity of our findings. Second, no data were collected on which specific training regimen was undertaken in the months leading up to the testing. We assumed that this training regimen was fairly homogeneous considering that these athletes were all collegiate swimmers from the same institution; however, differences in training may account for the differences between sexes. Finally, data were not collected on the years of participation in competitive swimming. This information might have been helpful in identifying swimmers with more ingrained upper quarter motor patterns. In general, although these limitations exist, they were consistent across groups and likely had a minimal effect on the overall outcome of the study.

In summary, female collegiate swimmers exhibited lower scores on the YBT-UQ than their male counterparts. Future authors should assess if worse performance on the YBT-UQ is associated with an elevated risk of injury, particularly in athletes with an elevated incidence of upper quarter injuries (eg, baseball, swimming, volleyball). The YBT-UQ scores reported in this study can be used as a normative level of upper quarter functional performance and functional symmetry in collegiate swimmers. Swimmers with core or upper quarter functional deficit or asymmetry may be identified through screening using the YBT-UQ and comparing their scores with the values reported in this study.

CONCLUSIONS

Collegiate female swimmers exhibited lower scores on the YBT-UQ than their male counterparts. In contrast, no differences between sexes were observed for asymmetry in any of the reach directions. These results may help in assessing upper quarter function when progressing swimmers in dry-land training aimed at improving swimming performance.

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