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Influence of a Single Swim Training on the Scapular Position and Isometric Muscle Strength in Young Swimmers

Annemie Van de Velde, Kristof De Mey, Patrick Calders, and Ann Cools

The purpose of our study was to investigate the influence of a single swim training on isometric scapular muscle strength and the static position of the scapula in a sample of 30 healthy adolescent swimmers who were measured on two sessions at a local aquatic center. Fatigue as result of a single swim training session may influence scapular position and strength. Measures included isometric evaluation of serratus anterior and upper trapezius peak isometric force using a push and shrug procedure, serratus anterior to upper trapezius strength ratios, and a semi-dynamic evaluation of lateral scapular displacement employing the Kibler method. When tested using a repeated-measures ANOVA, none of the strength parameters changed significantly as a result of the single swim training. Adolescent swimmers did employ higher values for the serratus anterior than for the upper trapezius. In the three positions of the LSST, the lateral displacement of the scapula increased significantly after the training ($p = 0.001, p < .001, p < .001$) and a minor scapular asymmetry was found. ($p = 0.037, p = 0.011, p = 0.005$). The highest LSST values were present on the dominant side, at both test moments.

The role of the scapula is a well documented topic in overhead sports (Borsa & Laudner, 2008; Kibler, 1998; Myers, Laudner, Pasquale, Bradley, & Lephart, 2005). Many studies have addressed scapular muscle activity and scapular biomechanics in various populations of upper extremity athletes, like throwing athletes, tennis players, and gymnastic athletes (Cools, Geeroms, Van den Berghe, Cambier, & Witvrouw, 2007; Donatelli et al., 2002; Wilk, Meister, & Andrews, 2002). Swimming has been cataloged as one of the overhead sports, but it has its own specific properties. Considering the constant horizontal position, the water medium as a training context and propulsive function of the upper extremities, comparisons with other sports are difficult to make.

The five functions of the scapula as described by Kibler (1998) can be applied to swimming. First, as an essential link in the kinetic chain, the scapula provides an appropriate transfer of muscular force from lower to upper extremities (Kibler, 1998). This is extremely important in a full kinetic open chain movement like swimming. Second, the scapula stabilizes the glenohumeral joint (Kibler, 1998). This

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means that the center of instantaneous rotation can function within a physiological pattern throughout swim cycles. Third, the scapular muscles have an important function during swimming (Nuber, Jobe, Perry, Moynes, & Antonelli, 1986; Pink, Perry, Browne, Scovazzo, & Kerrigan, 1991). Particularly the serratus anterior, which maintains activity throughout the swim cycle, is considered to be the key stabilizing shoulder girdle muscle in freestyle swimming (Nuber et al., 1986; Pink et al., 1991). The upper trapezius and rhomboids are active primarily during hand entry and exit (Pink et al., 1991). Fourth, the cyclic character of swimming requires a smooth succession of scapular protraction and retraction. Finally, adequate scapular elevation, tilting up the acromion and enlarging the subacromial space, is necessary to avoid shoulder impingement (Kibler, 1998). Especially during the recovery phase in freestyle, the swimmer's shoulder is considered to be at risk for impingement (Pink & Tibone, 2000).

Considering the high sport-specific demands of swimming, a swimmer's shoulder is often involved in shoulder problems and the incidence of pain is high. Although there is no simple or complete understanding of swimmer's shoulder pain, impingement of the subacromial structures has been hypothesized as a major cause of shoulder pain (Allegrucci, Whitney, & Irrgang, 1994; Olivier, Quintin, & Rogez, 2008; Pink & Tibone, 2000; Su, Johnson, Gracely, & Karduna, 2004; Wadsworth & Bullock- Saxton, 1997). With approximately 2,500 shoulder revolutions during typical training sessions, swimming definitely can be considered as an exhausting sport for the upper extremities. Consequently, local muscular fatigue as a result of a single training session seems to be a likely consequence. The serratus anterior is the muscle that is working at nearly its maximum with each swim stroke and is believed to be the most susceptible to fatigue (Nuber et al., 1986; Pink et al., 1991). According to Murphy (1994), muscle fatigue in swimmers is one of the leading factors in stroke breakdown and in the onset of pathological shoulder symptoms.

As stability at the scapulothoracic joint depends specifically on the surrounding musculature to resist fatigue, proper scapular kinematics requires adequate scapular muscle function (Borsa & Laudner, 2008; Kibler, 1998). Weakness or fatigue of periscapular muscles can be a contributing factor in scapular dyskinesis, abnormal movements of the scapula (Cools et al., 2002; Crotty & Smith, 2000; Laudner, Stanek, & Meister, 2008; Szucs, Navalgund, & Borstad, 2009). Several authors discussed the cause-and-effect relationship between scapular dysfunction and several shoulder pathologies (Cools, Witvrouw, & Mahieu, 2005; Ludewig & Cook, 2000; Lukasiewicz & Mcclure, 1999). Fatigue of the scapular muscles may be a mechanism contributing to shoulder pathologies by altering scapular motions and requiring compensation by other shoulder muscles (Szucs, Navalgund, & Borstad, 2009). After a serratus fatiguing task, higher activation of the upper trapezius was shown to occur while the serratus anterior/lower trapezius activation ratio was altered (Szucs, Navalgund, & Borstad, 2009). Fatigue of the serratus anterior/upper trapezius force couple can provoke impingement as a result of decreased upward rotation and hence narrowing within the subacromial space (Ludewig & Cook, 2000; Lukasiewicz & Mcclure, 1999). Furthermore, subacromial impingement is often attributed to altered scapular kinematics and changed activation of both serratus and trapezius muscles (Cools, Witvrouw, & Mahieu, 2005; Ludewig & Cook, 2000; Lukasiewicz & Mcclure, 1999).

Due to the requirement of upper extremity endurance in swimming, additional knowledge concerning the effects of acute serratus anterior muscle fatigue might be valuable. Considering the important role the serratus anterior muscle plays during the swim stroke and its connection to shoulder pathologies, the characteristics of scapular action following a swim training session are of interest. It was therefore the purpose of our study to investigate the effects of short term fatigue on scapular muscle activation as well as scapular position.

Method

Participants

Thirty healthy, young swimmers (15 males, 15 females) were recruited from three Flemish swimming clubs to participate in the study. Their average age was 15.6 ± 1.6 years (range, 13–18 years); they had a mean height of 162 ± 11.2 cm (range, 148–184 cm); and their mean weight was 52.3 ± 13.6 kg (range, 39–86 kg). Exclusion criteria for participation in the study were any history of shoulder surgery, current symptoms related to the cervical or thoracic spine, and the presence of shoulder pain that interfered with swim training. Before participation, informed consent was obtained from all participants and their legal guardians. This study was approved by the ethics committee of Ghent University.

Testing Procedures

All measurements were completed at the pool area of the swim team. The procedure consisted of two testing sessions, one no more than 30 min before and one no more than 10 min after a regular training session 2 hr in duration. All measures were administered by the same researcher who was familiar with the testing procedures.

The position of the scapula was determined by the lateral scapular slide test or LSST, which is described by Kibler (1998). The LSST is a quantitative, semidynamic method to determine lateral displacement of the scapula. Several studies (Kibler, 1998; Mckenna, Cunningham, & Straker, 2004; Odom, Taylor, Hurd, & Denegar, 2001) found acceptable intraclass correlation coefficient (ICC) values for intratester (ICC between 0.81 and 0.94) and intertester (ICC between 0.77 and 0.88, depending on the test position) objectivity. A radiographic validity study showed a correlation of 0.91 between the LSST and the same position on radiographic evaluation (Kibler, 1998). Measurements of the scapular position in an athletic sample appear to be as reliable as in a nonathletic sample (Mckenna, Cunningham, & Straker, 2004). The LSST describes three test positions whereby the distance between the inferior angle of the scapula and the nearest spinous process is measured (Kibler, 1998). In this study, we used a common measuring tape to determine that distance. In the first position the participant stood with both arms relaxed at the sides (Figure 1). For the second position, the participant was instructed to place hands on the hips, which resulted in 10 degrees of extension, some internal rotation and about 45 degrees of glenohumeral abduction (Figure 2). In the third position the shoulders were abducted to 90 degrees with full internal rotation (Figure 3). In each of the positions the midpoint of the inferior angle of the scapula was indicated as reference point and marked with a dermographic pencil. The spinous process was marked at the beginning and remained the same for all measurements. For each of the positions we completed three trials; the average was used for statistical analyses.

Figure 1 — First position: The participant stood with both arms relaxed at the sides to measure the distance between the inferior angle of the scapula and the nearest spinous process.

Figure 2 — Second position: Participant was instructed to place hands on the hips, which resulted in 10 degrees of extension, some internal rotation, and about 45 degrees of glenohumeral abduction.

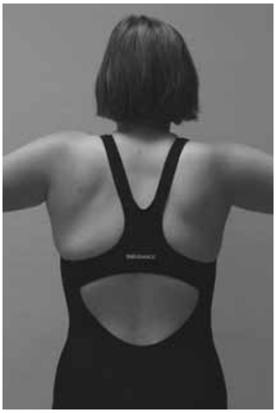

Figure 3 — In the third position, the shoulders were abducted to 90 degrees with full internal rotation.

Scapular strength tests were performed using hand-held dynamometry. Several studies (Donatelli et al., 2002; Mullaney et al., 2005; Trakis et al., 2008) reported the validity and reliability of testing upper extremity strength with a hand-held dynamometer. We used a Microfet2© hand-held dynamometer. A stabilizing system was designed for the study, based on the study of Su et al. (Su, Johnson, Gracely, & Karduna, 2004). The dynamometer was attached to a metal pole that was connected to a metal base. A towel was used to minimize sliding on the metal base. The height between the metal base and the dynamometer could be adjusted, depending on the participant's arm length or shoulder height.

We used a shrug maneuver to assess the strength of the upper trapezius muscle (Su et al., 2004). Participants sat on a chair that was placed on the metal base. The dynamometer was placed on top of the acromion process of the arm. The isometric movement was a scapular elevation with the shoulder moving toward the homolateral (i.e., same side) ear (Figure 4). All participants practiced using three submaximal repetitions before a single maximum isometric shrug was performed for 5 s. Between trials, a minute of rest was obligatory. Both left and right sides were tested. We always started with the dominant side. We determined the dominant side by identifying which arm the subject used to throw a ball.

To assess the strength of the serratus anterior muscle, a push maneuver was performed (Su et al., 2004). The participants lay supine on the metal base with the tested arm in full elbow extension and pronation. The glenohumeral joint was flexed for 90 degrees in the sagittal plane. We instructed the participants to place the heel of the hand against the dynamometer (Figure 5). Grabbing the dynamometer with the fingers was not allowed. The test protocol was the same as in the shrug movement. During the trial, verbal encouragements and, if necessary, performance

Figure 4 — Scapular elevation with the shoulder moving toward the homolateral ear.

Figure 5 — The participants lay supine on the metal base with the tested arm in full elbow extension and pronation. The glenohumeral joint was flexed for 90 degrees in the sagittal plane. Participants placed the heel of the hand against the dynamometer.

corrections were given by the examiner. The schedule of testing (LSST, shrug or push) was randomized to prevent sequencing effects. Both procedures had been used in previous studies (Mckenna, Cunningham, & Straker, 2004; Su et al., 2004).

Statistical Analyses

After data collection, we calculated means and standard deviations for all dependent variables: push and shrug forces before and after swim training on both sides of the body and LSST at 3 positions before and after swim training and on both sides as well. In addition, the agonist/antagonist strength ratio was calculated, with the push value as agonist and the shrug value as antagonist. We used the Kolmogorov-Smirnov test to check the normality of the data distribution. As the data distributions were different for strength values and LSST values, separate statistical analyses were completed. The LSST values were distributed normally with equal variances. We tested for statistically significant changes using a parametric general linear model 2-way analysis of variance (ANOVA) with repeated-measures design in which the within-subjects factors were time (2 levels) and side (2 levels). Interaction effects of time and side, as well as main group effects, were of interest. In the presence of a significant interaction effect, differences between groups and sides of the body were tested post hoc at each level of the interacting variable using a Bonferroni adjustment. In the absence of significant interactions, main effects of group were analyzed. The Type I error rate (α) was set at 0.05. For each of the multiple pair-wise comparisons, the Bonferroni adjustment adjusted the α to 0.025. Because the strength variables were not normally distributed, we applied nonparametric tests using a Wilcoxon related-samples procedure. With the SPSS software, the mathematical differences in strength and strength ratio between the pre/post test and the dominant/nondominant side were computed and tested using a Wilcoxon related-samples procedure. All statistical analyses were performed using SPSS (version 15.0; SPSS Inc, Chicago, IL).

Results

Peak Force and Ratio

Table 1 summarizes the descriptive data and the results from the Wilcoxon tests for peak force and ratio, at both test moments, on both sides of the body, and for both movements (shrug and push). The Wilcoxon tests showed no significant differences between sides of the body, not at the pretest (shrug: $p = 0.079$, push: $p = 0.797$ and ratio: $p = 0.491$) nor at the posttest (shrug: $p = 0.399$, push: $p = 0.600$ and ratio: $p = 0.853$). In summary, no significant strength differences between sides of the body (dominant vs. nondominant side) were found. When we compared the difference between the sides of the body (dominant side minus nondominant side), we did find a significant disordinal interaction on the shrug parameter ($p = 0.008$). The dominant side increased between pre- and posttests, whereas the nondominant side decreased. These results are presented in Table 2. No differences in test moments (pretraining versus posttraining) were found within the strength parameters for the dominant (shrug: $p = 0.360$, push: $p = 0.600$, and ratio: $p = 0.206$) or nondominant side (shrug: $pp = 0.104$, push: $p = 0.658$, and ratio: $p = 0.853$). These results are summarized in Table 1.

LSST

The descriptive data for the three positions of the LSST, at both test moments and at both sides of the body, are summarized in Table 3. For all of the LSST positions, the 2-way repeated-measures ANOVA showed significant main training effects for both sides ($p < 0.001$, $p = 0.001$, $p < 0.001$). In all of the three positions, the LSST values were significantly higher after the swim training. A significant main effect for side differences was revealed at all three positions ($p = 0.037$, $p = 0.011$, $p = 0.005$). The LSST value on the dominant side was significantly higher in all three positions.

Discussion

Peak Force and Ratio

Within this study, we found no significant influence of the single, two-hour swim training on any of the strength parameters. No significant muscle fatigue that resulted in decreased peak forces occurred in our sample. Apparently, the training was insufficient to cause measureable muscle fatigue. We considered it satisfactory to learn that a single training bout did not produce significant detriments in muscle strength. A comparable study had found significant drops in force production in both serratus anterior and upper trapezius after a swim training (Su et al., 2004). These swimmers were older, so their age could have been a deciding factor. Perhaps

Table 1 Mean (± *SD*) of Shrug (Peak Force, in Newtons), Push (Peak Force, in Newtons) and Ratio (Push/shrug) Regarding Time (Pre/Post) and Side (Dominant/ Nondominant) Differences (*N* = 30)

	Dominant			Non Dominant			P Value for Side Differences	
Variable	**Pre Test**	**Post Test**	**P Value for Training Differences**	**Pre Test**	**Post Test**	**P Value for Training Differences**	**Pre Test**	**Post Test**
Shrug	346.07 (± 128.85)	333.44 (± 132.62)	0.360	324.23 (± 143.56)	349.00 (± 155.63)	0.104	0.079	0.399
Push	429.34 (± 145,68)	438.17 (± 123.56)	0.465	434.15 (± 144,45)	437.89 (± 146.56)	0.658	0.797	0.600
Ratio	1.29 (± 0.34)	1.42 (± 0.49)	0.206	1.34 (± 0.37)	1.33 (± 0.32)	0.853	0.491	0.447

Table 2 Mathematical Differences (in Newton) Between Both Sides (Dominant Minus Nondominant), at Both Test Moments for the Parameters Shrug, Push, and Ratio. (*N* = 30)

Variable	Pre Test	Post Test	P-Value (Wilcoxon)
Side difference Shrug	21.48	–15.56	0.008
Side difference Push	–4.81	0.28	0.813
Side difference Ratio	–.05	0.09	0.202

*: significant difference (pre/post; p < 0.05)

Table 3 Mean (Standard Deviations, ±) of the Three Positions (LSST 1, LSST 2, LSST 3) of the LSST (in cm) Regarding Training (Pre/Post) and Side (Dominant/ Nondominant) Differences (*N* = 30)

	Dominant		Non Dominant			
Variable	Pre Test	Post Test	Pre Test	Post Test	P Value for Side Differences	P Value for Training Differences
LSST 1	9.67 * (± 1.02)	9.98 * • (± 1.05)	9.57 * (± 0.94)	9.82 *• (± 0.96)	0.037	0.001
LSST 2	10.41* (± 0.89)	10.80 * • (± 0.92)	10.32 * (± 0.95)	10.57 * • (± 0.93)	0.011	< .001
LSST 3	11.38 * (± 0.94)	11.71 * • (± 1.05)	11.26 * (± 0.95)	11.53 * • (± 1.01)	0.005	< .001

*significant main effect training (pre/post; $p < 0.05$)

•: significant main effect side (dominant/non dominant; $p < 0.05$)

older swimmers were more sensitive to fatigue as a result of many years of hard training. Moreover, in a sample of baseball pitchers, no drops in scapular muscle strength were found as result of their training (Mullaney et al., 2005). In the baseball study, however, the glenohumeral muscles did show a reduction in isometric power. Maybe scapular muscles are more resistant to fatigue compared with glenohumeral muscles in overhead movements. In spite of these findings, we could not entirely exclude the possibility of some muscle fatigue being present. Our test protocol measured only peak force measurement. In isokinetic muscle assessment, the fatigue index is used to determine muscle fatigue (Cools et al., 2007; Cools, Witvrouw, & Mahieu, 2005). Using a comparable parameter in isometric muscle testing could be valuable to detect muscle fatigue. With respect to injury prevention in a demanding endurance sport like swimming, measuring decrements in muscle endurance should be more valuable than examining changes in absolute strength as measured by peak torque. In this study, we used the shrug and push movements only to determine scapular muscle strength (or single repetition maximum repetition of force production). Because of the lack of activity in the middle and lower parts of the trapezius muscle during the shrug movement, this measurement isn't appropriate to evaluate the entire function of the trapezius muscle (Ekstrom, Donatelli, & Soderberg, 2003). Separate muscle tests for the three parts of the trapezius might have provided more qualified information.

Apparently a single swim training session was not sufficient to detect any muscular strength changes. A long term follow up period might allow detecting changes in strength to be more likely. In the future, it could be interesting to verify the influence of a longer training period (like an entire swim season) on the fatiguing effect of the scapular muscles. As an alternative for strength measurements, EMG analysis has proved to be a reliable tool to detect changes as a result of fatigue. In their study, Cools et al. (2002) found significant differences in latency times in the trapezius muscle after a fatiguing protocol. The muscle activation pattern was significantly delayed but not altered. Delayed muscle onset time, due to fatigue, could possibly lead to altered scapular kinematics (Cools et al., 2002; Diederichsen et al., 2008). In further research, this method can be more appropriate to detect subtle fatigue signs in swimmers than the pattern itself. In the literature, there has been a lack of EMG data concerning the influence of fatigue on scapular muscle behavior in swimmers that the current study undertook to detect.

The difference between both sides of the body was significantly altered during the post test. We can conclude that both sides responded differentially to the training. Although the absolute data revealed no significant changes, the dominant side seemed to be more susceptible to fatigue for some unexplained reason. Although swimming is considered to be a bilateral upper extremity sport, some authors have reported the presence of arm dominance in swimming strokes. These studies were mainly interested in the glenohumeral muscles (Gozlan et al., 2006; Seifert, Chollet, & Allard, 2005). In an isokinetic study, scapular muscle asymmetry was found in young swimmers. Significant side differences in scapular retraction strength were shown (Van de Velde, De Mey, Maenhout, Calders, & Cools, in press).Muscle ratios, concerning the agonist to antagonist relationships, provided important information about muscle balance around a joint. In our study, the ratio illustrated a virtual equality in serratus anterior to upper trapezius balance, instead of a protractor to retractor balance. We suggest that in the literature, a plain retraction movement more typically has been used to determine such a ratio (Cools et al., 2007; Cools, Witvrouw, & Mahieu, 2005). In a nonathletic adult population, the protractor to retractor ratio was found to be about 1.0 (Cools, Witvrouw, & Mahieu, 2005). In a group of adolescents, however, the ratio was slightly higher than 1 (Kibler, Chandler, Shapiro, & Conuel, 2007). This might be an age-specific adaptation. In our study, ratios between 1.29 and 1.42 were found. Due to the major function of the serratus anterior in swimming, this can be considered a sport-specific adaptation (Nuber et al., 1986; Pink et al., 1991). With respect to the age group of our test population, the appearance of adolescent secondary growth could have been an influence as well.

LSST

In this study, LSST values significantly increased after the two hour training period. This contrasts with the results of Crotty and Smith (2000), who found no significant changes at the posttraining period. In their study, only male swimmers were tested, and only the first position of the LSST was included (Crotty & Smith, 2000). Electromyographic evaluation has shown that very few muscles are working during the first position (Kibler, 1998). Only in the third position do scapular stabilizing muscles work at 40% of their maximum contraction (Kibler, 1998). Consequently, the first position is less appropriate to detect fatigue in scapular muscles (Crotty & Smith, 2000).

According to Kibler (1998), higher LSST values could be a result of the fatigue of the scapular stabilizers and therefore considered as disadvantageous. The relevance of the LSST is generally still under debate. Currently, no validity studies regarding scapular muscle fatigue and changes in LSST are available in literature. Our results suggested the presence of an altered scapular position after a swim training session, but we cannot explain this result. We must remark that an increased distance between the inferior angle and the spinal process could be a result of increased upward rotation. Especially in the second and third test position, sufficient upward rotation during elevation is necessary to avoid impingement (Kibler, 1998). As lateral displacement of the scapula contributes in upward rotation, an increased LSST could be considered as beneficial. The absence of strength decrements in our study may support this assumption. Only one previous study had examined the influence of short term fatigue on scapular upward rotation in swimmers (Su et al., 2004). In a group of healthy swimmers no changes occurred after a swim training session, whereas in swimmers with some shoulder impingement syndrome, a decrease in scapular upward rotation was found (Su et al., 2004).

After a fatiguing exercise of the shoulder, Thomson and Mitchell (2000) found a greater lateral glide of the scapula. Their results suggested that fatigue of the shoulder musculature can affect the scapular stability. Because our study measured scapular muscles only, we cannot support or refute these findings.

In our study, there was a main effect for body side differences concerning the LSST. Although swimming is considered a bilateral sport, some left to right differences were noted. This can be seen as a sport specific adaptation, resulting in a minor scapular dyskinesis. It is possible our laterality finding is related to the presence of a preferential breathing side in the front crawl (freestyle). Obviously, further study of this finding is warranted.

Within our study, we only took short term adaptations into account. In a recent follow-up study (Thomas, Swanik, Swanik, & Huxel, 2009) upper extremity athletes (including swimmers) were tested before and after a 12 week sports season. In the second position of the Kibler measurement, values significantly decreased after 12 weeks of training. This indicated more scapular retraction occurred at the end of the season, which is an important result in terms of injury prevention.

Conclusions

Our study purpose was to determine differences in isometric scapular strength and scapular position after swim training in a population of healthy adolescent swimmers. After a swim training session of two hours, no significant changes in serratus anterior and upper trapezius strength were found. A significant increase in scapular lateral displacement did occur after a swim training session. Based on our research, young swimmers may be characterized as suffering minor scapular dyskinesis and a muscular serratus anterior to upper trapezius ratio that was higher than 1. More research is necessary to detect sport specific adaptations of scapular and shoulder girdle muscles in swimmers on a short term as well as on a long term basis.

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