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## BILATERAL AND ANTERIOR-POSTERIOR MUSCULAR IMBALANCES IN SWIMMERS

**Ted Becker and Rod Havriluk**
*Everett Pacific Industrial Rehabilitation and Swimming Technology Research, USA.*

The purpose of this study was to determine the relative magnitude of bilateral and anterior-posterior differences in swimmers. Peak hand force was measured during aquatic exercise (horizontal arm abduction and adduction in a standing position) and swimming (freestyle and backstroke). The peak force values were significantly higher ($p<.01$) for exercise adduction than abduction and for the swim stroke with the arm in the adducted position (freestyle) rather than the abducted position (backstroke). The magnitude of the anterior-posterior difference was large for both exercise (1.5σ) and swimming (.8σ). Bilateral differences were trivial (.1σ, ns) in comparison. A training regimen that strengthens the arm abductors may not only decrease the incidence of injuries in all four strokes, but also increase hand force and, therefore, improve performance in backstroke.

Key Words: biomechanics, injury, technique, measurement, strength, evaluation.

### INTRODUCTION
Bilateral imbalances are common in swimmers and can inhibit performance (6). Anterior-posterior differences are not only common, but also related to injuries such as shoulder impingement (2, 7). Muscular balance in the shoulder and scapula is necessary to avoid injuries (8). The ratio of land-based abduction to adduction strength was used to quantify anterior-posterior differences and was correlated to clinical signs of injuries in swimmers (1). The purpose of this study was to determine the relative magnitude of water-based bilateral and anterior-posterior differences in swimmers, relate these imbalances to complementary clinical screening procedures, and suggest related changes to training regimens.

### METHOD
The subjects were 19 competitive swimmers (12 males and 7 females) between the ages of 14 and 17. The descriptive statistics for the males were: age (M = 15.4 yrs, SD = 1.4), height (M = 176 cm, SD = 7.9), and mass (M = 66.4 kg, SD = 9.9). The female data were: age (M = 15.4 yrs, SD = 1.4), height (M = 164 cm, SD = 7.5), and mass (M = 53.2 kg, SD = 5.4). Informed consent was obtained.
Peak hand force was measured performing aquatic exercise (horizontal shoulder abduction and adduction in a standing position) and swimming (freestyle and backstroke) with Aquanex (previously described and validated in 5). For the aquatic exercise, subjects were instructed to perform five repetitions with maximum intensity. For the swim trials, the subjects were asked to sprint 20 m to a wall. Hand force data were collected over the last 10 m. Two trials of each test were performed with about 1 min rest. The single highest peak force value for each trial was used as the criterion.

### RESULTS
Sample exercise and swimming trials are shown in Figures 1 and 2.

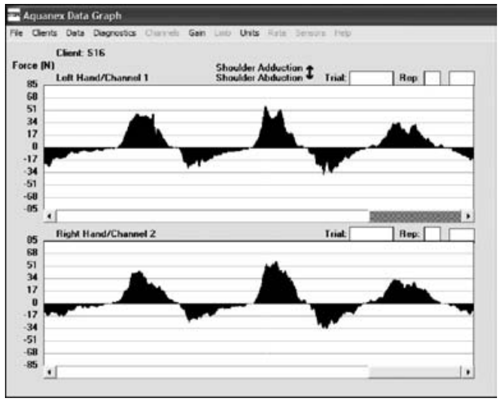


*Figure 1. Aquanex image of horizontal shoulder abduction/adduction exercise.*

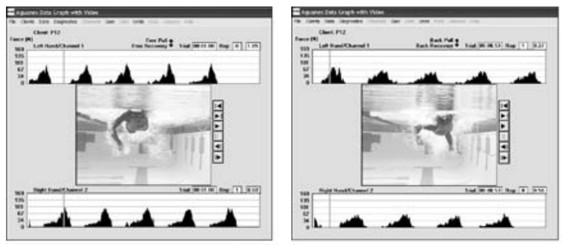

*Figure 2. Aquanex+Video images of freestyle and backstroke swimming.*

For aquatic exercise, the peak hand force values were significantly higher ($p<.01$) for adduction than abduction. For swimming, the peak hand force values were significantly higher ($p<.01$) for the stroke with the arm in the adducted position (freestyle) than in the abducted position (backstroke). Bilateral differences were not significant. The data are listed in Table 1 and graphed in Figure 3.

*Table 1. Peak hand force values (N), reliability coefficients (Alpha), and effect sizes (ES) for aquatic exercise and swimming.*

| | Abduction/Backstroke | | | Adduction/Freestyle | | | |
|---|---|---|---|---|---|---|---|
| | Alpha | M | SD | Alpha | M | SD | ES (σ) |
| Exercise/Left Hand | .87 | 34.4 | 16.5 | .97 | 75.7 | 34.1 | 1.63 |
| Exercise/Right Hand | .97 | 35.7 | 19.9 | .98 | 79.4 | 38.6 | 1.49 |
| Swimming/Left Hand | .88 | 120.5 | 33.4 | .94 | 148.1 | 50.4 | .66 |
| Swimming/Right Hand | .95 | 116.0 | 33.9 | .95 | 154.2 | 49.6 | .91 |

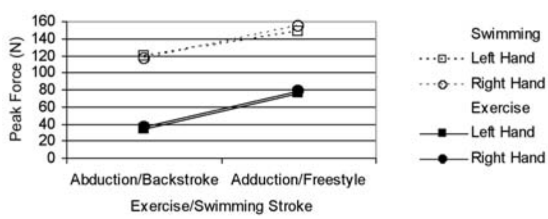


*Figure 3. Peak hand force values for aquatic exercise and swimming.*

**DISCUSSION**

The magnitudes of the anterior-posterior differences were large for both aquatic exercise (1.5σ) and swimming (.8σ). The anterior-posterior peak force ratios for aquatic exercise were similar to the values reported for land-based exercise (1, 4). The magnitude of these imbalances is less than ideal and can be related to performance restrictions and predisposition for shoulder injury.

Muscular imbalances and injuries have been attributed to stroke mechanics, inadequacies in dryland exercise, and overuse (2, 3, 8, 9). Although these are substantial issues, a coach can address each one in a typical training environment. For example, a coach can first conduct a technique analysis to qualitatively assess the mechanical basis for muscular differences. The freestyle recovery of the swimmer in Figure 4 shows a bilateral difference in the angle between the upper arm and the horizontal. The restricted right shoulder position reflects a strength decrement in shoulder abduction.

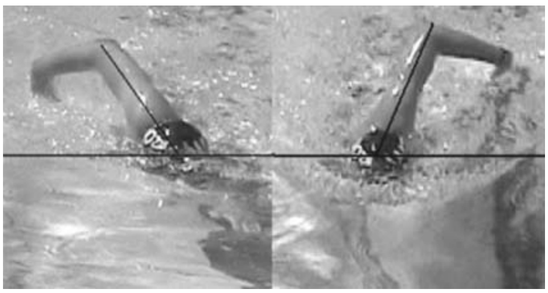

*Figure 4. Stroke evaluation of freestyle recovery showing a smaller angle with the horizontal for the weaker right shoulder.*

Such qualitative clinical evaluations can also identify related structural conditions. Testing that mimics the stroke mechanics can show muscular imbalance/stabilization dysfunction. The Swim Stroke Pull Test (Figure 5) is a dryland replication of the freestyle arm motion. The swimmer's hand directs force against the resistance of the examiner's hand to imitate the propulsive phase of the stroke. Strength decrement in shoulder adduction can be determined by qualitative analysis of the swimmer's force, body segment adjustments during the test, and video review. The scapular position for the affected right upper extremity shows dysfunctional elevation/protraction (Figure 6).

*Figure 5. Swim Stroke Pull Test. Swimmer is initially positioned with upper extremity at full shoulder abduction and then applies pressure to the examiners hand to complete shoulder adduction.*

*Figure 6. Comparative demonstration of upper extremities completing the Swim Stroke Pull Test. Left upper extremity shows adduction position with no irregularities. Right upper extremity shows irregular position of the scapula and indicates weakness of the adductor function.*

Once a structural problem is detected, a coach can implement changes in the training regimen. Specific strength training that targets the associated abductors can be added to the program. An adjustment of total training distance and the proportion of frontal stroke (butterfly, breaststroke, and freestyle) to dorsal stroke (backstroke) distance may also be appropriate.

**CONCLUSIONS**

Muscular imbalances of considerable magnitude are common in swimmers. A thorough strategy for dealing with muscular imbalances includes a minimum of three components: evaluation, remedial strength training, and adjustment of training distance and stroke. First, it is important to evaluate anterior-posterior muscular differences either quantitatively or qualitatively. Second, additional aquatic and/or land-based strength training may be necessary. Third, it may be appropriate to reduce the total training distance for the frontal strokes and/or increase the proportion of backstroke. A training regimen that strengthens the arm abductors may not only improve muscular balance and decrease the incidence of injuries in all four strokes, but also increase hand force and, therefore, performance in backstroke.

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