A Physiological and Shoulder Injury Profile of Elite Divers

Benjamin D. Rubin, T. Jeff Chandler, Steven J. Anderson, W. Ben Kibler

North Tustin Sports Medicine Center, Santa Ana, Calif.;
Lexington Clinic Sports Medicine Center, Lexington, Ky.;
Bellevue, Wash., USA

Diving is a sport that requires strength, agility, balance, timing, courage and quickness. With platform divers striking the water at 33 mph, it is not surprising that with the increasing difficulty of dives being performed, the incidence of reported injuries has also escalated [1-3]. Although a significant number of shoulder injuries have been observed at the elite level, there is no information in the literature concerning the exact incidence of shoulder injury in competitive divers. It has been suggested that the remarkable increase in shoulder problems may be related to the flat hand entry technique which has been popularized in the last 20 years, as well as the technique of 'swimming' entries on impact [1-4].

In an attempt to clarify some of the causative factors in the incidence of shoulder problems in competitive divers. 20 elite divers were evaluated for shoulder injuries and physiological measurements of strength, endurance, range of motion, and shoulder pathology as part of an elite training camp held at Lexington, Kentucky in September, 1991. The study was conducted with multiple purposes in mind. First, to determine the incidence of clinically significant shoulder injuries in this elite population. Second, observations on divers have revealed a significant change in the position of the scapula (elevation and protraction) when the arms went from the position in which the hands were brought together overhead (grab position) to the position of maximum shoulder elevation (lock-out position) [3]. We attempted to quantitate the change in scapular position and determine the components thereof. Finally, Kibler [5] has used the measurement of lateral slide of the scapula as a measure of strength deficit in the scapular stabilizing musculature of tennis players. Using shoulder injuries in tennis players as a
Table 1. Age, height, weight, sex, and years of diving experience for participants in the study

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th></th>
<th>Females</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>SD</td>
<td>mean</td>
<td>SD</td>
</tr>
<tr>
<td>Age, years</td>
<td>23.3</td>
<td>3.4</td>
<td>22.8</td>
<td>4.2</td>
</tr>
<tr>
<td>Height, cm</td>
<td>169.9</td>
<td>4.8</td>
<td>160.3</td>
<td>6.9</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>69.6</td>
<td>7.1</td>
<td>56.1</td>
<td>7.3</td>
</tr>
<tr>
<td>Years of experience</td>
<td>12.7</td>
<td>5.3</td>
<td>11.8</td>
<td>6.1</td>
</tr>
</tbody>
</table>

model, we studied elite divers to determine if there is a relationship between injury and lateral scapular slide, range of motion, strength and power, direction of twisting maneuvers, or relative position of the hands on impact with the water.

It is our hope that by identifying the factors associated with shoulder injuries in competitive divers, that we might reduce the number of injuries that limit or prevent continued training and competition.

**Methods**

Twenty divers from the US National Team who were taking part in an elite training camp during September 1991 were participants in the study. The average age, height, weight, and years diving experience are recorded in table 1. Each athlete completed a general health questionnaire as well as a questionnaire specific to the sport of diving which included information on years of experience, hand position on entry into the water, direction of twisting, and a detailed history of shoulder injuries. Examinations were performed by physicians experienced in musculoskeletal evaluations. The exams included evaluations of general posture, scapular mechanics, manual muscle testing, measurement of scapular slide in five positions, and clinical tests of stability, impingement, and inflammation [6].

Lateral scapular slide measurements were obtained in the three positions described by Kibler [5]: (1) arms at side, (2) hands on hips, (3) 90° of humeral abduction with maximum internal rotation, and in two additional positions: (4) grab position, and (5) reach position. The latter two positions are sport specific for diving. The grab position was obtained by asking the athlete to join his/her hands overhead in the position in which they do when diving. The reach position was obtained as the athlete 'locked out' as in preparation for entering the water. Overhead reach was measured in the grab and reach positions. Divers were seated on a stool with their backs against a wall. The maximum overhead reach was measured in the grab and reach positions, with the difference between the two measurements being recorded. Goniometric measurements were obtained for shoulder internal and external rotation, flexion, extension, abduction, horizontal abduction and horizontal adduction.

Isokinetic strength tests of shoulder external/internal rotation and flexion/extension were performed using a Cybex 340 Isokinetic Dynamometer. All isokinetic tests were per-
formed using protocols from the manufacturer (Cybex, Ronconcoma, N.Y., USA). Internal/external rotation measurements were obtained in the supine position with 90° of humeral abduction.

The data were analyzed using analysis of variance to compare the symptomatic (n = 21) to the asymptomatic (n = 19) shoulders, and to compare the symptomatic shoulders paired with asymptomatic shoulders in a single athlete (n = 13). Correlation statistics were performed on the symptomatic shoulders paired to asymptomatic shoulders to determine if injury was related to direction of twist or hand position on entry.

Results

Of the 20 divers, 16 reported shoulder injuries associated with diving, which limited their training for at least 1 week at some time during their careers. Nine athletes had diagnosed patterns of instability, including subluxations and/or dislocations. Three of these athletes had bilateral injuries. Nine athletes were diagnosed as having inflammatory problems (including impingement syndrome and/or tendinitis), and 2 had acromioclavicular joint injuries. Six athletes had bilateral shoulder injuries. There were no male/female differences.

In comparing isokinetic data in the group of symptomatic to asymptomatic shoulders, peak torque in external rotation and peak torque/body weight ratio in external rotation were significantly less in the injured extremity (p < 0.05). In the comparison of the symptomatic shoulders paired to the asymptomatic shoulders, peak torque in external rotation was significantly less in the symptomatic shoulder (p < 0.05). Peak torque to body weight ratios were also significantly less in the asymptomatic shoulders paired with a symptomatic shoulder (p < 0.01). In all cases the ratio of internal rotation to external rotation ranged from 1.7 to 2.0:1 and the ratio of extension of flexion was 1.5:1. There was no difference between symptomatic and asymptomatic shoulders.

Lateral scapular slide measurements revealed no significant differences in symptomatic versus asymptomatic shoulders or in the symptomatic shoulders paired with an asymptomatic shoulder in any position of abduction. Goniometric measurements of shoulder range of motion did not differ between symptomatic and asymptomatic groups.

Correlations of shoulder injury with both top hand on entry and with direction of twist were calculated in the 13 divers with one injured extremity. The correlation coefficient for shoulder injury and top hand on entry was +9.43, while that for shoulder injury and direction of twist was −0.28. Thus, there was minimal relationship between these variables and shoulder injuries.

1 Tables available on request.
Shoulder elevation measured as the difference between the grab and reach position against the wall averaged 11.2 cm (± 5.1), with no statistically significant difference between men 12.4 (± 3.0) and women 9.7 (± 6.3).

Discussion

The purpose of this study was threefold: (1) to determine the incidence of clinically significant shoulder injuries in elite competitive divers; (2) to determine if there is a relationship between shoulder injury and lateral scapular slide, range of motion, strength and power, direction of twisting maneuvers, or relative position of hands on impact with the water; and (3) to assess whether the change in the position of the scapula from the grab to the reach or lock-out position was solely due to scapulothoracic motion, or if other factors were involved in the movement of the shoulder girdle.

There is inherent difficulty with the reproducibility of clinical assessment of manual muscle strength, goniometric measurements and lateral scapular slide. However, since all clinical assessments were done by the same clinicians during the same examination period, the incidence of error was reduced as much as possible. The questionnaires regarding injuries did not specify whether injuries occurred during springboard or platform diving; comparison of the incidence of injuries in the two events is not possible.

For the purposes of this study, an injury was considered clinically significant if it caused the athlete to miss at least 1 week of training. The incidence of such injuries in this elite group of divers was 80%. Injuries were classified as problems of instability, inflammation and acromioclavicular joint injury for purposes of simplification. The injury pattern was similar to gymnastics and swimming [7, 8, McMaster, pers. commun., 1991] and included acute subluxations and dislocations as well as primary and secondary traction tendinitis involving the rotator cuff and long head of biceps. Impingement syndrome secondary to instability was frequent; however, primary impingement was quite rare.

Kibler [5] reported a significant difference in lateral slide in symptomatic versus asymptomatic shoulders in tennis players. Our study failed to demonstrate a significant difference between symptomatic and asymptomatic shoulders in elite divers. Perhaps this relates to the lack of arm dominance in this group of athletes and the position of the arm and shoulder during the sport-specific activity. In diving, the glenohumeral joint is placed in a mechanically ‘at risk’ position (180° abduction, 180° flexion, and maximum internal rotation, with no inferior support). It may be more at risk in the lock-out position due to anterior or anterior-superior translation of the humeral head. This position is not supported by the bony anatomy or most of the large muscle groups. This is distinctly different from the throwing motion (95–100° abduction, 45–90° forward flexion and horizontal abduction). It
would be interesting to study lateral scapular slide in other sports in which there is no known upper extremity dominance, such as gymnastics or swimming. Surprisingly, there was no correlation between measurement of the lateral scapular slide in the overhead position and the absolute difference between wall measurements in the grab and reach positions. This probably indicates that the movement of the shoulder girdle during this action involves more than purely scapulothoracic motion, perhaps anterior or anterior/superior glenohumeral translation.

Significant differences were observed in symptomatic versus asymptomatic shoulders with regard to external rotation strength for peak torque (p < 0.05) and peak torque/body weight (p < 0.01), with the asymptomatic shoulders being stronger. These results are similar to those that have been reported in tennis players [9], swimmers [10], and water polo players [11]. No relationship was demonstrated between direction of twisting or hand position on impact with the water.

This study clearly documents a high incidence of shoulder injuries in elite competitive divers. Cybex isokinetic evaluations demonstrated a significant reduction in the peak torque and peak torque/body weight in external rotation in injured extremities. No relationship was documented between injury and lateral scapular slide, range of motion, direction of twisting maneuvers, or relative position of the hands on impact with the water. Future studies will include the development of strengthening programs to determine if they will affect the incidence of shoulder injuries in this select group of athletes.

References


Benjamin D. Rubin, MD, North Tustin Sports Medicine Center, 720 North Tustin Avenue, Suite 206, Santa Ana, CA 92705 (USA)