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Title: The Relationship of Selected Biomechanical Components to the Presence of Swimmer's Shoulder in Experienced Age-Group Swimmers

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Seventy-six competitive swimmers from eight swimming teams were surveyed about swimmer's shoulder symptoms over the past year, then were placed into symptomatic levels: nonsymptomatic and symptomatic with the symptomatic sample divided into moderately and highly symptomatc levels.

Swimmers were videotaped to evaluate maximum body roll and the simultaneous angle of the upper arm to the horizontal plane--lateral abduction of the shoulder. Elbow extension at mid-recovery was also measured. Measurements were taken during right and left breathing and nonbreathing cycles.

Mean measurements for the components demonstrated numerous significant differences in the body roll and lateral abduction components. Few significant differences were found in elbow extension. The results indicate a relationship between mechanics and swimmer's shoulder.

The Relationship of Selected Biomechanical Components to the Presence of Swimmer's Shoulder in Experienced Age-group Swimmers

by

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CHAPTER I

INTRODUCTION

Swimming is generally considered to be a sport which involves a low incidence of injuries to participants; however, swimmers do suffer from various orthopaedic manifestations. The most common of these manifestations is a form of tendinitis which primarily affects the supraspinatus tendon and to a lesser degree the biceps brachii tendon. This manifestation is commonly referred to as swimmer's shoulder. There is strong evidence which suggests swimmer's shoulder is caused by the repetitive impingement of the supraspinatus and biceps brachii tendons (2,9,22,23,24,27,30). As a result of these findings swimmer's shoulder is referred to in much of the literature as impingement syndrome.

Certain biomechanical variations of form or improper techniques have been linked to impingement syndrome in throwing athletes (1,8,17,32). With regard to swimming, technique has been theorized to be a contributing factor to the impingement syndrome problem (6,28).

Statement of the Problem

To determine if stroke mechanics during the recovery phase of the freestyle stroke in swimmers contribute to the development of impingement syndrome (swimmer's shoulder).

Need for the Study

Published research regarding swimmer's shoulder has developed a solid base for the physiological cause of chronic shoulder pain in swimmers, but has not contributed to increased knowledge regarding factors which may be attributed to the development of swimmer's shoulder in some swimmers, while others performing the same training regimine are unaffected. Further research is required to develop an understanding of mechanical characteristics which may be used to determine which swimmers may have a higher risk of developing swimmer's shoulder. This will allow coaches to correct abnormalities before tendinitis is allowed to develop. A basis for other technique-related studies may also be established.

Delimitations

The study compared selected biomechanical components in the recovery of the freestyle stroke among swimmers who have (a) not developed symptoms of swimmer's shoulder, (b) developed symptoms of swimmer's shoulder which have not affected performance or training, and (c) developed symptoms of swimmer's shoulder which have had an effect on the swimmers' ability to train or compete within the past year. Competitive swimmers over 12 years of age with at least 3 years continuous year-round training who have achieved "A" National Time Standards in at least 2 freestyle events were studied.

Limitations

Some swimmers may have fabricated their shoulder problems. Variations in training intensity over a given period or the physiological structure of the shoulder joint may allow some subjects to be free of symptoms even though they have stroke abnormalities which may normally have contributed to development of swimmer's shoulder.

Methodology

The study involved 76 swimmers from 8 swim teams in Arkansas and Indiana, including the state age-group/senior champion teams from both states. Swimmers in the study were asked to complete a questionnaire which addressed shoulder pain experienced over the past year. After the survey was completed and discussed with the swimmers' coaches, swimmers were placed in one of three categories for each shoulder: nonsymptomatic (NS), moderately symptomatic (MS), and highly symptomatic (HS). Swimmers were then videotaped to evaluate selected biomechanical components of the freestyle recovery. The following components were evaluated for right and left arms for both breathing and nonbreathing recovery cycles by way of videotaping: degree of mid-recovery elbow extension; degree of lateral abduction of the shoulder during maximum body roll; and maximum degree of body roll.

A prestudy videotaping session was used to determine the best camera position for viewing the selected recovery components. The optimum camera position was found to be 8 feet from the edge of the water and 35 inches above the water surface. In addition, videotaping the swimmer from behind produced the best images of the body roll, avoiding interference caused by the head, bow wave, and excessive splashing. The camera was adjusted to a 6X magnification and positioned at the center of the swimming lane to film the swimmers from 15 to 60 feet from the edge of the pool. Measurements were taken for both arms during breathing and nonbreathing recovery cycles and mean measurements for each category (NS, MS, and HS), as well as the total symptomatic sample (MS + HS = TS), were determined for each biomechanical component. The means for these categories were compared utilizing t-ratios to determine where significant differences existed at a .95 confidence level ($p < .05$) (10). Comparisons of means were performed between the following categories: NS and MS; NS and HS; NS and TS; as well as MS and HS.

Definition of Terms

The following definitions are given for terms used throughout this study:

A.LB: The degree of lateral abduction of the shoulder during maximum body roll during freestyle recovery on the left side while breathing on that side.

A.LNB: The degree of lateral abduction of the shoulder during maximum body roll during freestyle recovery on the left side while not breathing on that side.

A.RB: The degree of lateral abduction of the shoulder during maximum body roll during freestyle recovery on the right side while breathing on that side.

A.RNB: The degree of lateral abduction of the shoulder during maximum body roll during freestyle recovery on the right side while not breathing on that side.

B.LB: The maximum degree of body roll during freestyle recovery on the left side while breathing on that side.

B.LNB: The maximum degree of body roll during freestyle recovery on the left side while not breathing on that side.

B.RB: The maximum degree of body roll during freestyle recovery on the right side while breathing on that side.

B.RNB: The maximum degree of body roll during freestyle recovery on the right side while not breathing on that side.

E.LB: The degree of elbow extension during freestyle recovery on the left side while breathing on that side.

E.LNB: The degree of elbow extension during freestyle recovery on the left side while not breathing on that side.

E.RB: The degree of elbow extension during freestyle recovery on the right side while breathing on that side.

E.RNB: The degree of elbow extension during freestyle recovery on the right side while not breathing on that side.

HS: Those subjects reporting levels of pain in their shoulder which are highly symptomatic of swimmer's shoulder.

MS: Those subjects reporting levels of pain in their shoulder which are moderately symptomatic of swimmer's shoulder.

NS: Those subjects reporting levels of pain in their shoulder which are not symptomatic of swimmer's shoulder.

TS: Those subjects reporting levels of pain in their shoulder which are symptomatic of swimmer's shoulder. The combination of the moderately and highly symptomatic subjects.

Hypotheses

1. Ho: There exist no differences in the maximum body roll among nonsymptomatic, moderately symptomatic, and highly symptomatic swimmers.

2. Ho: There exist no differences in the lateral abduction of the shoulder at maximum body roll during freestyle recovery among nonsymptomatic, moderately symptomatic, and highly symptomatic swimmers.

3. Ho: There exist no differences in elbow extension during freestyle mid-recovery among nonsymptomatic, moderately symtomatic, and highly symptomatic swimmers.

All hypotheses will be tested by determining the differences between means for the selected biomechanical components at a .95 level of confidence ($p < .05$), using degrees of freedom as determined by the total number of subjects in the two groups being compared minus two. A hypothesis will be rejected when a t-ratio exceeds the determined level of significance for t ($p < .05$) in the corresponding component.

CHAPTER II

REVIEW OF LITERATURE

Introduction

A major cause of swimmer's shoulder is thought to be a lesion resulting from repeated impingement of the supraspinatus tendon and to a lesser extent the biceps brachii tendon near their insertions on the great tuberosity of the humerus (4,6,18,24,26). Impingement occurs between the anterior third of the acromium and the thick coracoacromial ligament and the head of the humerus (2,6,7,9,18,22,23). Several authors attribute this development of impingement lesions to an avascular zone present in these tendons as they are stretched over the head of the humerus and blood is forced out of the vascular bed (2,7,9,18,27,30). Thickening of the subacromial bursa in response to inflamation has also been cited as an aggravating factor leading to further impingement (16).

No previous studies have examined the role of stroke mechanics as a contributing factor in development of the impingement syndrome. Some authors have indicated that stroke mechanics may play a role in development of swimmer's shoulder (6,28) and there is evidence that variations in biomechanical form contribute to impingement syndrome in baseball pitchers (1).

Impingement of the Tendon

Injuries to the tendon insertions and the elastic elements of the muscle will occur at the height of the length-tension curve of the muscle (32). In swimmer's shoulder, the damage occurs to tendons, especially in avascular regions, when they become impinged between the head of the humerus and the subacromial bursa, the anterior third of the acromium, and/or the coracoacromial ligament (18,22,24). The impingement is centered on the supraspinatus tendon insertion, but often may also involve the adjacent long head of the biceps (24). Elevation of the arm with rotation brings the tendons against the anterior aspect of the acromium (20,22). The first abuttment in swimmers occurs as the forwardly flexed shoulder is internally rotated, bringing the critical zone of avascularity into the area of impingement. The second abuttment occurs during abduction of the internally rotated shoulder (26,9). At 80 degrees of abduction, the critical zone is brought directly under the impingement area (22). The greater tuberosity is also impinged against the lateral acromium and against the undersurface of the acromioclavicular joint with progressive abduction (14). These mechanical phases coincide with the pulling and recovery phases of the freestyle and butterfly strokes. Results indicate that freestyle and butterfly swimmers have the greatest incidence of orthopaedic manifestations of the shoulder (6,7,9,18,28).

Overhead work is the most common cause of bicipital tendinitis. The biceps originates above the glenoid rim and passes down through the bicipital groove. As a result, the tendon has a long course with extremes of motion and is easily damaged or inflamed during overhead work (12). In bicipital tendinitis, pain may extend down the arm (31).

Impingement of the avascular regions of the tendons leads to tissue degeneration and results in inflamation. The inflamation and resulting edema cause further impingement of the tendons. The increased tension causes an increased area of avascularity to develop contributing to further degeneration (2,19,27). Chronic degeneration found in swimmer's shoulder is believed to be a result of the repeated impingement which occurs in swimmers during training (7,9,18,22).

Young athletes usually have a gradual onset of soreness which intensifies if they continue the activity (3). Competitive swimmers under 25 years of age who experience symptoms of swimmer's shoulder normally manifest the first stage of the impingement syndrome identified by reversible edema and hemorrhage (23,24). If the healing process is repeatedly interrupted by reinjury, then the healing process itself becomes pathalogic (4).

Swimmer's shoulder may be diagnosed as bursitis; but, if present, it is generally a secondary condition. Bursitis is rarely the primary cause of an orthopaedic manifestation (13,15,17); however,development of bursitis may further contribute to the severity of the impingement by further encroaching on the subacromial space (16).

Avascular Zones in Tendons

Studies have revealed that under normal conditions, tendons are capable of withstanding any stress which the muscle can apply to it, and the muscle would tear from any external stress before the tendon (21,27,30). Ischemic zones in tendons are, however, extremely vulnerable; therefore, an ischemic tendon may tear from quite minor stress. A small capsular tear is most common in supraspinatus tendons (2,27,30).

Rathbun and McNabb (27), using microangiography with cadavers soon after death, found that this zone of avascularity was greatly decreased when the arm was abducted passively from the adducted internally rotated position in which the cadavers had previously been tested. Further inspection led them to conclude that the vascular bed of the tendons were "wrung out" by pressure from the head of the humerus at the point where they stretched across it when the arm is held down to the side and inwardly rotated. Repeated arm elevation and the degree of upper arm elevation are the most important factors affecting the load placed on the shoulders (13). Avascularity is accentuated by the high intramuscular pressure which results when the arm is elevated. For this reason, shoulders are most vulnerable to injury when involved in repeated overhead work (15).

Previous Studies Concerning Swimmer's Shoulder

Several studies have dealt directly with the problem of swimmer's shoulder. In a study by Kennedy, Hawkins, and Krissoff (18), 1978, olympic swimmers from Canada were observed in preparation for the 1972 and 1976 Olympics for orthopaedic problems. In 1972, 16 of 35 subjects had shoulder problems which required consultations with a physician, whereas in 1976, only 4 of 38 subjects developed such manifestations. The decreased incidence was attributed to better education of physicians, coaches, and parents concerning the recognition and treatment of the overuse syndrome. A continuation of the study was engineered in the form of a nationwide survey among prominent Canadian swimming teams. Included in the survey were 2496 swimmers. The average daily workload was 5000 yards. Only 81 complaints of swimmer's shoulder were received. The national figure represents an incidence of 3.25 percent, while the olympian incidence was 45.7 percent in 1972 and 10.5 percent in 1976.

Dominguez (7), 1978, conducted a 2-year study which included 144 swimmers from a championship YMCA swimming team and a private high school boys' swimming team. Of all age groups involved, the 13 to 18 year-old boys had the highest incidence of shoulder pain during and immediately after practice--27 of 46 (58.7 percent). Five of the 27 who developed shoulder pain were unable to attend some practice sessions or meets due to the problem. According to Dominguez, "Informal conversations with various swimmers and coaches seem to indicate that shoulder pain occurs in more than three percent of the swimmers in the United States" (p. 108). He reports that his study indicates that over 50 percent of all swimmers will have some shoulder pain, and that more than 10 percent will have shoulder pain which will cause them to miss practice sessions or swimming meets.

In his 1980 study, Dominguez (6) found 57 percent of the 40-member United States World Championship Team (1978) had a history of shoulder pain. He associated the increase in incidence over studies performed in the early 1970s with the increase in daily training distances over the years. He found distance freestyle and butterfly swimming to be the most common offenders. His observations led him to theorize that improper mechanics such as abduction with progressive internal rotation may lead to impingement syndrome.

Richardson, Jobe, and Collins (28), 1980, evaluated 137 swimmers from the Olympic Training Center and the United States World Championships Team and found 58 (42.3 percent) with swimmer's shoulder. The study found the incidence of swimmer's shoulder problems increased with age and ability and was greatest in elite female swimmers (68 percent). The overall incidence was, however, greater in males (46 percent to 40 percent). Distance swum during practice sessions was not found to be a significant factor; however, use of handpaddles increased pain in swimmers with manifestations. Seventy-five percent of swimmers reporting pain experienced that pain both during recovery and pulling. Decreased body roll and increased shoulder flexion were theorized to increase the liklihood of impingement. After evaluation with slow-motion underwater photos, the authors concluded, "Research into the technical difference between those subjects with shoulder pain and those without will shed light on what swimming technique changes can be made to prevent swimmer's shoulder" (p. 163). With regard to freestyle, it was determined that body roll was likely to be the most significant determinant of shoulder pain.

Fowler (9) and Neer (24) made observations which indicated a relationship between mechanics and shoulder problems. Neer commented that swimmers who breathe on only one side appear to be more susceptble and may be corrected by employing bilateral breathing. Fowler noted that swimmers with higher recoveries had less shoulder pain.

Greipp (11), 1985, evaluated 168 swimmers and found a clear correlation between lower shoulder flexibility and swimmer's shoulder. Weight training was also was found to increase the incidence of shoulder pain--possibly related to hypertrophy of the tendons. No relationship was found between swimmer's shoulder and stroke, distance, or sex; however, butterfly swimmers did demonstrate the highest incidence. Greipp indicated that authors who had attributed stroke mechanics to swimmer's shoulder were in fact observing a manifestation of lowered shoulder flexibility.

Swimming Biomechanics

Richarson, Jobe, and Collins (28) divide the freestyle recovery into three phases. The first stage is elbow lift. In elbow lift, the the shoulder begins abduction and external rotation and body roll begins in the opposite direction of the pull through. In the second stage, mid-recovery, the shoulder is abducted to 90 degrees and externally rotated beyond neutral. Body roll reaches a maximum of 40 to 60 degrees and breathing occurs. This differs from Counsilman's description of body roll at 35 to 40 degrees. (5). The final stage in recovery is the hand entry. This stage is characterized by external rotation and maximal abduction of the shoulder with body roll returning to neutral.

Other Biomechanical Considerations

Impingement often occurs as the arm reaches the horizontal plane (2,3). Pain on elevation may be aggravated by further external rotation and 85 to 140 degrees flexion (19,20). These motions are often associated with throwing-type activities. Hand motions in swimming heavily involve throwing-type motions (25) such as throwing a ball, a javelin, or using a racquet (4).

Albright, Jokl, Shaw, and Albright (1), 1978, used slow-motion movies of 18 college and 104 little league pitchers to compare delivery form with symptoms in the throwing arm. The incidence of these symptoms was found to increase with the age and ability of the subject and a correlation was found between the delivery form and the symptoms. Duda (8) and Jobe (17) also observed this relationship in their work with shoulder injuries in throwing athletes. Jackson (16) attributes shoulder problems in throwing athletes to external rotation.

As a result of his extensive work with impingement syndrome, Neer (24) advises tennis players to rotate the body on overhead hits and serves to avoid lateral abduction and associated injuries to the shoulder.

Summary

The core papers related to impingement syndrome have been written by Rathbun (27) and McNab (30). Both authors have been cited in much of the other literature concerning the subject. Literature on the impingement syndrome is well developed and without significant disagreement. In addition, the cause of swimmer's shoulder is agreed upon by all authors to be a manifestation of the impingement syndrome. The literature directly related to swimmer's shoulder is concentrated on determining the incidence, prevention, and treatment of swimmer's shoulder. Research concerning prevention of swimmer's shoulder has centered on flexibility and strength training. Some authors have suggested that training habits or stroke mechanics may play a role in the development of swimmer's shoulder; however, no scientific research has been conducted in these areas.

CHAPTER III

METHODOLOGY

The study was designed to evaluate the freestyle recovery techniques of swimmers comparing the means of selected components for swimmers exhibiting varying degrees of swimmer's shoulder symptoms to determine if differences exist in stroke characteristics which demonstrate an association which may serve as a contributing factor in the development of swimmer's shoulder.

Sample Description

The subjects of the study included 76 swimmers from Indiana and Arkansas, including the state age-group/senior championship teams from each state. Subjects were older than 12 years of age and each had a minimum of 3 years continuous year-round competitive swimming training. In addition, the subjects were required to have met the "A" National Time Standard in at least two freestyle events. These restrictions were used to establish a congruency within each sample. In addition, these restrictions allowed the study to focus on the swimmers which experience the highest incidence of shoulder problems (6,7,28).

Swimmer's Shoulder Symptoms

Recent swimmer's shoulder was evaluated by the use of a questionnaire adapted from Greipp (11). The swimmers rated their shoulder pain during the past year on a scale of 0 to 7, rating the right and left shoulders separately. The pain levels included on the survey were as follows:

0. No pain.

1. A little pain every now and then, no problem.

2. Hurt periodically after practice.

3. Hurt often during practice.

4. Pain was annoying for perhaps 8 hours a day and could have affected my ability to practice hard.

5. Pain was very annoying and definitely affected my ability to practice hard.

6. Hurt bad, at least 12 hours a day, unless ice or medication was used. Almost impossible to practice hard.

7. Impossible to train normally or compete--forced to miss some training or competition.

Swimmers who reported pain levels of 0-2 in either the left or right shoulder were categorized as nonsymptomatic (NS) for the indicated shoulder(s). Swimmers reporting pain levels of 3-4 were categorized as moderately symptomatic (MS), and those reporting pain in levels 5-7 were classified as highly symptomatic (HS). The combination of the MS and HS pain categories was classified as the total symptomatic (TS) category. This classification system resulted in the development of eight categories for each measured biomechanical component: right shoulder NS, MS, HS, and TS and left shoulder NS, MS, HS, and TS.

Data Collection Procedures

Stroke mechanics were evaluated through the use of a video camera above deck level and centered at the end of the swimming lane where videotaping was conducted (see Figure 1). Prestudy videotaping was conducted to determine the most productive viewing approach for above water analysis of the selected biomechanical recovery components. The most effective position was determined to be 8 feet from the edge of the water and 35 inches above the water surface. Optimum camera magnification was determined to be 6X magnification, viewing the pool between 15 and 60 feet from the edge of the water (between the backstoke areas at either end of the pool).

Instructions to Subjects

Subjects were briefed about the general nature of the study and informed of the importance of their honesty in both answering the questionnaire and swimming using a normal workout stroke. Subjects were advised that the

Figure 1. Investigator Videotaping Subjects

intent of the study was to evaluate the strokes they use every day in practice--including breathing patterns.

Videotaping Procedures

Videotaping was conducted after a normal warm-up session for the team being taped. Videotaping sessions were all in late October and early November at each team's pool. All teams had been training for 5 to 8 weeks during the short course season. Subjects were videotaped as they swam into the camera--from the front, and then as they swam away from the camera--from the rear. Prestudy videotaping revealed body roll was often obscured from the front by the head, bow wave, or excessive splashing; therefore, measurements were taken only from the rear--as the subjects were swimming away from the camera.

Videotaping was conducted using a Sylvania Newvicon camera, model number VCC 127BK01, with a 1:1.2 lens, autofocus, and X6 zoom and a Sylvania portable four-head VHS recorder, model number VC4545SL01. The camera was mounted on a tripod centered 8 feet from the edge of the water surface and adjusted to place the base of the camera at 35 inches above the water's surface.

Subjects were assigned identification (ID) numbers upon completion of the questionnaire. The numbers consisted of three digits with the first number corresponding to the taping series. There were five series: one series, the 500-series included three teams, the 300-series included two teams, and the other three series, the 100, 200, and 400-series, included one team each. The subjects were then filmed in order of their ID number, using the second and third digits to indicate the order within each series. Subjects' ID numbers were voiced into the microphone of the video camera to ensure accurate matching when the videotape was reviewed.

Biomechanical Components

Body roll was measured by determining the maximum degree of deviation of the upper back from the horizontal position (see Figure 2).

Lateral abduction of the shoulder was determined by measuring the deviation of a line through the center of the upper arm from the horizontal position during maximum body roll and subtracting that measurement from the simultaneous body roll measurement (see Figure 2).

Elbow extension at mid-recovery was measured by determining the angle between lines through the center of the upper arm and the forearm at mid-recovery (see Figure 2).

Figure 2. Subject at Mid-Recovery During Left Nonbreathing Cycle

Evaluation of Video Data

Measurements were taken from the first right and left, breathing and nonbreathing cycles after the subjects performed a turn and two transition strokes, providing a maximum of four measurements for each of the three biomechanical components. For bilateral breathers (swimmers who breathe on both sides), the product was 12 biomechanical components. These components are as follows: for body roll--right nonbreathing (B.RNB), right breathing (B.RB), left nonbreathing (B.LNB), and left breathing (B.LB); for lateral abduction of the shoulder the four corresponding components are A.RNB, A.RB, A.LNB, and A.LB; and for elbow extension E.RNB, E.RB, E.LNB, and E.LB. Subjects who did not breathe bilaterally were evaluated during the breathing and nonbreathing cycles which existed. This resulted in two measurements for each component for subjects who breathed every stroke and three measurements for swimmers who breathed every other stroke (breathing on the same side alternating breathing and nonbreathing cycles). The product of all pain categories and biomechanical components yielded 96 samples, 8 for each of the 12 biomechanical components, to be used in testing the hypotheses.

The videotape was reviewed and measurements taken using the Sylvania four-head VHS recorder in the single-frame advance, stop action, and slow-motion modes to determine measurements of the selected biomechanical components. The videotapes were reviewed on a Sears 20 inch square-screen television with a transparent sheet mounted on the television screen. Each component described previously was determined by use of a minimum of four viewings for each measurements. First, the entire sequence after the two transition strokes were observed at normal speed to detrmine breathing patterns. Second, each evaluated cycle was observed at slow motion to determine the general recovery pattern. The third viewing used single-frame advance and stop action marking mid-points on the forearm and upper arm, as well as the upper back as the subject appeared to be nearing maximum body roll. Once the measurement point was determined, the lines were charted and a final viewing was made at slow motion as the subject swam through the charted area.

Data Reduction Procedures

Once all the measurements were recorded, the information from the questionnaire and the biomechanical component measurements were entered into a CONDOR data base management system file developed by the investigator to record and sort the 12 components by the 8 pain categories.

After the subjects and their biomechanical component measurements were sorted into the eight pain categories, the mean, standard deviation, and standard error of the mean were determined for each of the 96 samples. T-ratios were found by comparing the means of the following groups for each of the 12 measurements: right NS vs MS, NS vs HS, NS vs TS, and MS vs HS; and left NS vs MS, NS vs HS, NS vs TS, and MS vs HS.

T-ratios were considered significant at the .95 level of confidence ($p < .05$). Ratios achieving a .90 level of confidence or a .99 level of confidence were annotated for information in consideration for any future studies in this area. However, the criteria for accepting or rejecting the null hypotheses was the .95 level of confidence (10).

CHAPTER IV

RESULTS

Overview

The purpose of the study was to determine if stroke mechanics during the recovery phase of the freestyle stroke in swimmers contribute to the development of impingement syndrome, more commonly referred to as swimmer's shoulder.

Twelve biomechanical components of the freestyle recovery were analyzed. These components included:

B.RB: Maximum body roll during right breathing cycles

B.RNB: Maximum body roll during right nonbreathing cycles

B.LB: Maximum body roll during left breathing cycles

B.LNB: Maximum body roll during left nonbreathing cycles

A.RB: Lateral abduction of the shoulder at maximum body roll during right breathing cycles

A.RNB: Lateral abduction of the shoulder at maximum body roll during right nonbreathing cycles

A.LB: Lateral abduction of the shoulder at maximum body roll during left breathing cycles

A.LNB: Lateral abduction of the shoulder at maximum body roll during left nonbreathing cycles

E.RB: Elbow extension at mid-recovery during right breathing cycles

E.RNB: Elbow extension at mid-recovery during right nonbreathing cycles

E.LB: Elbow extension at mid-recovery during left breathing cycles

E.LNB: Elbow extension at mid-recovery during left nonbreathing cycles

Means of these 12 biomechanical components were compared among the symptomatic groups for both right and left shoulders. These symptomatic groups were determined by pain levels and were nonsymptomatic (NS), moderately symptomatic (MS), highly symptomatic (HS), and the combined MS and HS subjects which were termed total symptomatic (TS).

The mean, standard deviation, and standard error of the mean were determined for each of the 96 samples produced by 12 biomechanical components and 4 symptomatic levels for both left and right shoulders. T-ratios were found by comparing the means of the following groups for each of the 12 measurements: right NS vs MS, NS vs HS, NS vs TS, and MS vs HS; and left NS vs MS, NS vs HS, NS vs TS, and MS vs HS.

T-ratios were considered significant at the .95 level of confidence ($p < .05$). Ratios achieving a .90 level of confidence or a .99 level of confidence were annotated for information in consideration for any future studies in this area. However, the criteria for accepting or rejecting the null hypotheses was the .95 level of confidence (10). The null hypotheses were as follows:

1. Ho: There exist no differences in the maximum body roll among nonsymptomatic, moderately symptomatic, and highly symptomatic swimmers.

2. Ho: There exist no differences in the lateral abduction of the shoulder at maximum body roll during freestyle recovery among nonsymptomatic, moderately symptomatic, and highly symptomatic swimmers.

3. Ho: There exist no differences in elbow extension during freestyle mid-recovery among nonsymptomatic, moderately symptomatic, and highly symptomatic swimmers.

Twenty-two of the 76 subjects (28.94%) reported moderate or highly symptomatic pain in one or both shoulders. The two state championship teams had incidences (TS) of 10/27 (37%) and 8/20 (40%), while the rest of the teams' combined TS was 4/29 (13.8%). Of the 22 symptomatic subjects, 10 were highly symptomatic (13.16%) and 12 were moderately symptomatic (15.79%). TS incidences demonstrated a tendency to increase with age (see Appendix B).

The number of subjects in the right and left pain categories varied since not all swimmers breathed bilaterally. The total number of swimmers reporting right shoulder pain in the NS category was 61. Right shoulder pain in the MS and HS categories totalled 8 and 7, respectively, resulting in a TS count of 15. Left shoulder pain totals were as follows: 63 NS, 8 MS, 5 HS, and 13 TS.

Body Roll

As expected, overall maximum body roll measurements (Table 1) were greater for breathing cycles in the overall results. Since 34 of the subjects breathed only on the right side, the LB sample was much smaller than the other three.

Table 1. Overall Maximum Body Roll Measurements (degrees).

	B.RB	B.RNB	B.LB	B.LNB
n (# subjects)	68	60	42	73
$\bar{X}$ (mean)	53.84	39.65	50.14	37.29
SD (standard deviation)	12.72	11.10	11.06	9.48

The findings with regard to body roll demonstrated significant differences between nonsymptomatic (NS) and symptomatic subjects (TS) in five of eight components (see

Tables 10 and 11 for the summary of t-ratios for body roll, left and right symptoms).

Both right side body roll components demonstrated significant differences in left shoulder symptoms as did the left breathing component (Tables 2, 3, and 4). The left nonbreathing component demonstrated a large difference between NS and TS subjects (Table 5), but was not significant ($p < .05$). Similar differences were found in comparisons of NS and the moderately symptomatic (MS) subjects for left shoulder symptoms, except that the differences in the left nonbreathing component were not as large.

Differences between symtomatic levels for the right shoulder were not as dominant; however, the right nonbreathing and left breathing components were different between NS and TS subjects. These differences were also exhibited in the NS and MS subjects; however, the left breathing component was not significant ($p < .05$) (Tables 6, 7, 8, and 9).

Only the right breathing component demonstrated differences between NS and highly symptomatic (HS) subjects and that only in the right shoulder. No differences were found between MS and HS subjects.

These results demonstrate a strong association between decreased body roll during recovery and the incidence of swimmer's shoulder, particularly moderate symptoms. Subjects in the lowest range of body roll measurements had higher TS incidences than those in middle range in seven of eight evaluated components, and higher TS, MS, and HS incidences than the highest range for all eight components.

As a result of the numerous significant differences ($p < .05$) found between the body roll measurements of NS subjects and MS and TS subjects, the null hypothesis stating no differences would exist between these subjects was rejected.

Table 2. Maximum Body Roll Measurements, Left Symptoms - B.RB (degrees).

	NS	MS	HS	TS
n	56	8	4	12
$\bar{X}$	55.96	43.63	44.50	43.92
SD	11.43	13.82	17.48	14.32
SE (standard error of the mean)	1.53	4.89	8.76	4.13

Table 3. Maximum Body Roll Measurements, Left Symptoms--B.RNB (degrees).

	NS	MS	HS	TS
n	49	6	5	11
$\bar{X}$	41.90	28.00	31.60	29.62
SD	10.10	7.75	13.13	10.12
SE	1.44	3.16	5.87	3.05

Table 4. Maximum Body Roll Measurements, Left Symptoms--B.LB (degrees).

	NS	MS	HS	TS
n	33	6	3	9
$\bar{X}$	51.94	43.33	44.00	43.56
SD	11.09	8.94	9.54	8.53
SE	1.93	2.45	5.51	2.84

Table 5. Maximum Body Roll Measurements, Left Symptoms - B.LNB (degrees).

	NS	MS	HS	TS
n	61	8	4	12
$\bar{X}$	38.31	32.88	32.00	32.58
SD	9.17	12.77	6.48	10.74
SE	1.17	4.51	3.24	3.10

Table 6. Maximum Body Roll Measurements, Right Symptoms - B.RB (degrees).

	NS	MS	HS	TS
n	56	7	5	12
$\bar{X}$	54.50	53.86	46.40	50.75
SD	13.15	13.36	5.37	11.07
SE	1.76	5.05	2.40	3.20

Table 7. Maximum Body Roll Measurements, Right Symptoms - B.RNB (degrees).

	NS	MS	HS	TS
n	49	6	5	11
$\bar{X}$	41.27	30.50	34.80	32.45
SD	11.47	5.13	6.83	6.07
SE	1.64	2.09	3.06	1.83

Table 8. Maximum Body Roll Measurements, Right Symptoms - B.LB (degrees).

	NS	MS	HS	TS
n	33	5	4	9
$\bar{X}$	51.82	45.60	42.00	44.00
SD	11.21	7.83	11.75	9.27
SE	1.95	3.50	5.87	3.09

Table 9. Maximum Body Roll Measurements, Right Symptoms - B.LNB (degrees).

	NS	MS	HS	TS
n	60	7	6	13
$\bar{X}$	37.83	34.00	35.67	34.77
SD	9.45	13.30	5.05	9.99
SE	1.22	5.03	2.06	2.77

Table 10. Comparison of Body Roll Means, Left Shoulder T-Ratios

	NS VS MS	NS VS HS	NS VS TS	MS VS HS
B.RB	2.41 *	1.29	2.73 **	.09
B.RNB	4.00 **	1.70 @	3.64 **	.39
B.LB	3.51 **	1.36	2.44 *	.11
B.LNB	1.14	1.83 @	1.73 @	.06

Significance levels ** = p<.01 * = p<.05 @ = p<.1

Table 11. Comparison of Body Roll Means, Right Shoulder T-Ratios

	NS VS MS	NS VS HS	NS VS TS	MS VS HS
B.RB	.12	2.55 *	1.03	1.25
B.RNB	4.05 **	1.75 @	3.59 **	1.16
B.LB	1.55	1.50	2.14 *	.53
B.LNB	1.01	.90	.76	.31

Significance levels ** = p<.01 * = p<.05 @ = p<.1

Lateral Abduction of the Shoulder

The difference between the body roll measurement and the angle the upper arm formed with a horizontal line at maximum body roll constitute this measurement. The resulting measurements included negative numbers--lateral shoulder adduction; positive numbers--lateral shoulder abduction; and zero--no lateral abduction or adduction.

Again, 34 of the subjects breathed only on the right side, resulting in the LB sample being much smaller than the other three. With the exception of the right nonbreathing cycle measurements, mean measurements were negative (see Table 12).

Table 12. Overall Lateral Abduction of the Shoulder (degrees).

	A.RB	A.RNB	A.LB	A.LNB
n	68	60	42	73
$\bar{X}$	-1.84	5.78	-6.74	-1.25
SD	9.45	9.02	9.88	8.38

Lateral abduction of the shoulder demonstrated significant differences between NS and TS subjects in five of eight components, and six of eight components between the NS and HS subjects (see Tables 21 and 22 for the summary of t-ratios for left and right symptoms).

Both right lateral abduction components demonstrated these differences in left shoulder symptoms as did the left nonbreathing component. The left breathing component demonstrated a large difference between NS and TS subjects, but was not significant ($p < .05$) (Tables 13, 14, 15, and 16).

As found in body roll analysis, differences between symptomatic levels for the right shoulder were not as dominant; however, the right nonbreathing and left breathing components were different between NS and TS subjects (Tables 17, 18, 19, and 20).

As opposed to results for body roll, only one significant difference was found in comparisons of NS and the MS subjects for left and right shoulder symptoms.

Differences between NS and HS subjects were found in six components--the largest number of components for any symptomatic level comparisons in the study.

These results demonstrate a strong association between the increased lateral abduction of the shoulder during maximum body roll in swimmers during freestyle recovery and the presence of swimmer's shoulder, particularly severe symptoms. Subjects in the highest range of lateral abduction measurements had higher TS and HS incidences than those in the middle and lower ranges in seven out of the eight evaluated components.

As a result of the numerous significant differences ($p < .05$) found between the lateral abduction measurements of NS subjects and the HS and TS subjects, the null hypothesis stating no differences would exist between these subjects was rejected.

Table 13. Lateral Abduction Measurements, Left Symptoms - A.RB (degrees).

	NS	MS	HS	TS
n	56	8	4	12
$\bar{X}$	-3.25	1.00	12.25	4.75
SD	8.03	13.49	8.30	12.31
SE	1.07	4.77	4.15	3.71

Table 14. Lateral Abduction Measurements, Left Symptoms--A.RNB (degrees).

	NS	MS	HS	TS
n	49	6	5	11
$\bar{X}$	3.86	13.00	16.00	14.36
SD	8.15	9.14	6.93	7.97
SE	1.16	3.73	3.10	2.40

Table 15. Lateral Abduction Measurements, Left Symptoms--A.LB (degrees).

	NS	MS	HS	TS
n	33	6	3	9
$\bar{X}$	-8.76	-4.00	10.00	.67
SD	7.71	12.13	13.89	13.86
SE	1.34	2.45	8.02	4.59

Table 16. Lateral Abduction Measurements, Left Symptoms - A.LNB (degrees).

	NS	MS	HS	TS
n	61	8	4	12
$\bar{X}$	-2.64	2.88	12.00	5.92
SD	7.53	9.60	3.16	9.03
SE	.96	2.83	1.58	3.46

Table 17. Lateral Abduction Measurements, Right Symptoms - A.RB (degrees).

	NS	MS	HS	TS
n	56	7	5	12
$\bar{X}$	-2.14	-2.57	2.60	- .42
SD	9.43	8.79	12.20	10.17
SE	1.26	3.32	5.46	2.93

Table 18. Lateral Abduction Measurements, Right Symptoms - A.RNB (degrees).

	NS	MS	HS	TS
n	49	6	5	11
$\bar{X}$	3.98	8.17	20.60	13.82
SD	7.82	7.63	9.45	10.34
SE	1.12	3.11	4.23	3.12

Table 19. Lateral Abduction Measurements, Right Symptoms - A.LB (degrees).

	NS	MS	HS	TS
n	33	5	4	9
$\bar{X}$	-8.79	-4.40	7.25	.78
SD	8.07	10.45	14.50	13.08
SE	1.41	4.68	7.25	4.36

Table 20. Maximum Body Roll Measurements, Right Symptoms - A.LNB (degrees).

	NS	MS	HS	TS
n	60	7	6	13
$\bar{X}$	-1.12	- .86	-3.00	-1.85
SD	8.02	12.23	8.92	10.45
SE	1.04	4.62	3.64	3.61

Table 21. Comparison of Lateral Abduction Means, Left Shoulder T-Ratios

	NS VS MS	NS VS HS	NS VS TS	MS VS HS
A.RB	.87	3.62 **	2.07 *	1.80 @
A.RNB	2.34 *	3.67 **	3.94 **	.62
A.LB	1.70 @	2.31 *	1.69 @	1.15
A.LNB	1.85 @	7.92 **	2.16 *	2.81 **

Significance levels ** = p<.01 * = p<.05 @ = p<.1

Table 22. Comparison of Means, Right Shoulder T-Ratios

	NS VS MS	NS VS HS	NS VS TS	MS VS HS
A.RB	.12	.85	.54	.81
A.RNB	.79	3.80 **	2.97 **	2.37 *
A.LB	.90	2.17 *	2.09 *	1.26
A.LNB	.05	.50	.19	.07

Significance levels ** = p<.01 * = p<.05 @ = p<.1

Elbow Extension

The angle between the upper arm and the forearm made up the elbow extension measurement. The maximum possible measurement of 180 degrees (straight arm) was not exhibited in any of the subjects.

As with the other two components, the LB cycle had a small sample due to the large number of right-only breathing patterns (see Table 23).

Table 23. Overall Elbow Extension Measurements (degrees).

	E.RB	E.RNB	E.LB	E.LNB
n	68	59	41	73
$\bar{X}$	122.01	125.53	132.27	133.62
SD	20.57	22.41	19.46	18.51

Only one of eight measured components demonstrated significant differences between NS and TS subjects and NS and HS subjects. Two significant differences were found in each the NS and MS comparison and NS and HS comparison.

The MS means were consistently higher than the NS means. Conversely, the HS means were consistently lower than the the NS means. This suggested significant differences would be found between MS and HS subjects;

however, this was only the case in two of eight components (see Tables 32 and 33 for t-ratios for left and right shoulders).

Although there were twice as many significant differences in right shoulder symptoms as in left shoulder symptoms, four as opposed to two, three of these were in the E.RNB component and incidences of symptoms showed no consistent pattern between lower, middle, and upper ranges of measurements.

Significant differences ($p < .05$) were found in only 2 of 16 t-ratios for left shoulder symptom analysis. These were in the right nonbreathing cycle--NS and MS, and the left breathing cycle--NS and TS (see Tables 24, 25, 26, and 27).

Significant t-ratios were evidenced in three of the mean comparisons for the E.RNB component. The HS subjects' mean was significantly lower than the NS subjects' mean ($p < .01$). Conversely, the MS subjects' mean was significantly higher than that of the NS subjects ($p < .01$). As would be expected from these relationships, the MS and HS means were significantly different ($p < .01$). The only other significant difference occurred in the E.LB component between MS and HS subjects ($p < .01$) (see Tables 28, 29, 30, and 31).

Although the finding of significant differences (p<.05) in elbow extension measurements allows the rejection of the null hypothesis which states no differences would exist, the lack of consistent differences suggests those differences found may be attributed to the influence of body roll and/or lateral abduction of the shoulder on the elbow extension measurement.

Table 24. Elbow Extension Measurements, Left Symptoms - E.RB (degrees).

	NS	MS	HS	TS
n	56	8	4	12
$\bar{X}$	121.70	130.63	109.25	123.50
SD	20.98	17.15	16.58	19.31
SE	2.80	6.06	8.29	5.57

Table 25. Elbow Extension Measurements, Left Symptoms-- E.RNB (degrees).

	NS	MS	HS	TS
n	48	6	5	11
$\bar{X}$	124.88	138.83	115.80	128.36
SD	22.02	14.03	30.89	25.00
SE	3.18	5.73	13.81	7.54

Table 26. Elbow Extension Measurements, Left Symptoms--E.LB (degrees).

	NS	MS	HS	TS
n	33	5	3	8
$\bar{X}$	133.30	134.40	117.30	128.00
SD	19.87	14.67	21.39	18.21
SE	3.46	6.56	12.35	6.44

Table 27. Elbow Extension Measurements, Left Symptoms - E.LNB (degrees).

	NS	MS	HS	TS
n	61	8	4	12
$\bar{X}$	133.11	135.88	132.75	134.83
SD	19.89	15.69	9.39	13.53
SE	2.55	5.55	4.70	3.91

Table 28. Elbow Extension Measurements, Right Symptoms - E.RB (degrees).

	NS	MS	HS	TS
n	56	7	5	12
$\bar{X}$	121.32	130.29	118.20	125.25
SD	21.23	20.93	13.92	18.66
SE	2.84	7.91	6.22	5.93

Table 29. Elbow Extension Measurements, Right Symptoms - E.RNB (degrees).

	NS	MS	HS	TS
n	48	6	5	11
$\bar{X}$	124.35	146.00	112.20	130.64
SD	22.79	15.84	11.37	22.11
SE	3.29	6.45	5.08	6.67

Table 30. Elbow Extension Measurements, Right Symptoms - E.LB (degrees).

	NS	MS	HS	TS
n	33	4	4	8
$\bar{X}$	132.15	140.50	125.00	132.75
SD	21.30	10.88	7.75	12.04
SE	3.71	5.44	3.87	4.26

Table 31. Elbow Extension Measurements, Right Symptoms - E.LNB (degrees).

	NS	MS	HS	TS
n	60	7	6	13
$\bar{X}$	132.95	135.00	138.67	136.69
SD	19.20	22.18	10.41	17.17
SE	2.48	8.38	4.25	4.76

Table 32. Comparison of Elbow Extension Means, Left Shoulder T-Ratios

	NS VS MS	NS VS HS	NS VS TS	MS VS HS
E.RB	1.34	1.42	.29	2.08 @
E.RNB	2.13 *	.63	.43	1.54
E.LB	.15	1.25	2.09 *	1.22
E.LNB	.45	.07	.37	.43

Significance levels ** = p<.01 * = p<.05 @ = p<.1

Table 33. Comparison of Elbow Extension Means, Right Shoulder T-Ratios

	NS VS MS	NS VS HS	NS VS TS	MS VS HS
E.RB	1.07	.46	.65	1.20
E.RNB	3.17 **	3.05 **	1.04	4.12 **
E.LB	1.27	1.33	.11	3.69 **
E.LNB	.23	1.16	.70	.39

Significance levels ** = p<.01 * = p<.05 @ = p<.1

Incidence of Shoulder Symptoms

The incidence of shoulder symptoms was not statistically analyzed; however, the incidence levels by team, stroke, age, sex, and biomechanical component (upper third, middle third, and lower third of the sample) were recorded. These incidence levels are presented in Appendix B.

The more talented teams had a higher incidence of shoulder symptoms. Both state championship teams were well above the others: 37% and 40%. These results agree with findings by Richardson, Jobe, and Collins (28) which found an incidence of 42.3% among 137 highly talented swimmers. Incidences in less talented teams were lower. Although swimmers' level of ability was not evaluated, except as a minimum standard, these findings support the theory expressed by Richardson, Jobe, and Collins (28) that the incidence of swimmers' shoulder problems increases with ability.

Total incidences did not appear to be affected by stroke; however, discounting IM swimmers because of the small sample (n=3), the freestylers had a much higher incidence of highly symptomatic shoulders (20%).

There were some differences in incidence by age. The 13 year-old swimmers had less than half the incidence of the entire sample (14.2%). Sixteen and 17 year-olds had the highest incidences--40.0 and 36.4%, respectively. The incidence among males was slightly higher than females: 30.6 to 27.5%.

The incidences found in 76 swimmers studied by the investigator in nonmechanical components differ slightly in some areas with other studies; however, all the studies have dealt with a variety of performance levels as well as differing criteria for what constitutes swimmer's shoulder; therefore, conclusive comparisons are difficult to establish. Generally, there appears to be a strong link to ability and a moderate link to age. This is consistent with studies reporting incidence levels (1,6,7,28).

With regard to biomechanics, very high incidences were found in the upper range of lateral shoulder abduction and the lower range of body roll. Incidences in the middle ranges as well as the lower range of lateral abduction and the upper range of body roll were substantially lower, with as much as 42.8 percentage points difference (in the abduction--right nonbreathing (A.RNB) component for left shoulder symptoms). There are no published statistics for incidence by biomechanical components; therefore, no comparisons with other findings are possible.

Summary

Analyses of mean maximum body roll, lateral shoulder abduction, and mid-recovery elbow extension measurements demonstrated a large number of significant differences between swimmers' symptomatic levels for both right and left shoulders in the first two components. Few significant differences were observed for the elbow extension component. The summary of significant differences (p<.05) (table 34) demonstrates the strong association between swimmer's shoulder symptoms and the body roll and lateral abduction components. Also, evidenced in the table is the comparative lack of significance in the elbow extension component.

Table 34. Summary of Significance

	Left Shoulder				Right Shoulder			
X1:	NS	NS	NS	MS	NS	NS	NS	MS
X2:	TS	MS	HS	HS	TS	MS	HS	HS
B.RB	**	*					*	
B.RNB	**	**			**	**		
B.LB	*	**			*			
B.LNB								
A.RB	*		**					
A.RNB	**	*	**		**		**	*
A.LB			*		*		*	
A.LNB	*		**	**				
E.RB								
E.RNB		*				**	**	**
E.LB	*							**
E.LNB								

Significance Levels: * = p<.05 ** = p<.01 (ratios that were significant at p<.1 were presented in Tables 10, 11, 21, 22, 32, and 33)

CHAPTER V

DISCUSSION AND CONCLUSIONS

Discussion

The purpose of the study was to determine if stroke mechanics during the recovery phase of the freestyle stroke in swimmers contribute to the development of impingement syndrome, more commonly referred to in swimmers as swimmer's shoulder.

Published research has developed a solid basis for understanding the physiological cause of swimmer's shoulder. The research suggests the problem is caused by repetitive impingement of supraspinatus and biceps brachii tendons between the head of the humerus and the subacromial bursa, anterior acromium, and/or the coracoacromial ligament (2,6,7,9,18,22,23). Research related to swimming has centered on incidence of the problem with varying results (6,7,18,28). Generally, the results indicated incidence increased with the abilities and ages of the swimmers. In 1980, Richardson, Jobe, and Collins (28) also evaluated distance swum and found no relationship to swimmers' shoulder problems. The authors did, however, suggest that stroke mechanics should be investigated as a cause for the swimmer's shoulder problem. In particular, the authors indicated decreased body roll and increased shoulder flexion may be important determinants. Fowler (9) and Neer (24), also suggested stroke mechanics may be related to the problem, although no published research until this study dealt with the possible relationships between swimming mechanics and swimmer's shoulder.

In order to study the possible relationships between stroke mechanics and swimmer's shoulder, the investigator videotaped 76 swimmers on 8 swimming teams in both Indiana and Arkansas, including the state championship teams from both states. All videotaping was conducted during the fall term at each team's pool, 5 to 8 weeks after the beginning of the short course season.

Swimmers in the study were asked to complete a questionnaire which addressed shoulder pain experienced over the past year. After, the survey was completed and discussed with the swimmers' coaches, swimmers were placed in one of three categories for each shoulder: nonsymptomatic (NS), moderately symptomatic (MS), and highly symptomatic (HS). Swimmers were then videotaped to evaluate selected biomechanical components of the freestyle recovery. The following components were evaluated for right and left arms for both breathing and nonbreathing recovery cycles by way of videotaping: degree of mid-recovery elbow extension; degree of lateral abduction of the shoulder during maximum body roll; and maximum degree of body roll.

The camera was positioned 8 feet from the edge of the water and 35 inches above the water surface. Taping was conducted from behind to avoid interference caused by the head, bow wave, and excessive splashing. The camera was adjusted to a 6X magnification and positioned at the center of the swimming lane to film the swimmers from 15 to 60 feet from the edge of the pool. Measurements were taken for both arms during breathing and nonbreathing recovery cycles and mean measurements for each category (NS, MS, and HS), as well as the total symptomatic sample (MS + HS = TS), were determined. The means for these categories were compared utilizing t-ratios to determine where significant differences existed at a .95 confidence level ($p < .05$) (10). Comparisons of means were performed between the following categories: NS and MS; NS and HS; NS and TS; as well as MS and HS.

The result of the analyses demonstrated numerous significant differences in the body roll and lateral shoulder abduction and confirm the theory expressed by Richardson, Jobe, and Collins (28).

The analysis of elbow extension demonstrated few significant differences. The presence of some significant differences suggests further research of this component is in order, but are insufficient to support the observations by Fowler (9) who indicated that swimmers with higher recoveries appeared to have less shoulder pain.

The study discounts claims by Greipp (11) that authors who had attributed swimmer's shoulder to stroke mechanics were only observing lowered shoulder flexibility. Although flexibility was not studied, swimmers with lower flexibility would be required to use more body roll and would be less capable of lateral abduction in the recovery. This contradicts the findings in this study which indicate reduced body roll and increased abduction increase shoulder symptoms.

Body Roll

These results demonstrate a strong association between the amount of body roll reached by swimmers during recovery and swimmer's shoulder, particularly moderate symptoms. Subjects in the lowest range of body roll measurements had higher TS incidences than those in middle range in seven of eight evaluated components, and higher TS, MS, and HS incidences than the highest range for all eight components.

The cause for the significant differences in body roll measurements between NS and TS/MS subjects cannot be attributed soley to the effect body roll has on the impingement of the supraspinatus or biceps brachii tendon, since when isolated from any other biomechanical components a change in body position would not have any effect on the shoulder joint. Rather, the role reduced body roll plays in contributing to increased lateral abduction during recovery or to changes in the pulling phase of the opposite arm must be attributed to the increased symptoms.

Lateral Abduction of the Shoulder

The differences in lateral abduction of the shoulder between NS and TS/HS subjects are the strongest of the three evaluated biomechanical components. The likely cause for the relationship found between symptomatic levels is abuttment of the humerus and the coracoacromial ligament, anterior acromium, and/or subacromial bursa (18,22,24) and subsequent impingement of the supraspinatus tendon during mid-recovery where the arm begins its internal rotation (26,9). The biceps brachii tendon may also be stressed when lateral abduction stretches the biceps brachii tendon over the head of the humerus and causes an area of avascularity to develop (27).

Changes in the biomechanics of the pulling arm that result from the increased lateral abduction of the recovery may explain the cause for the relationship found between measurements of one shoulder and swimmer's shoulder symptoms in the other.

Elbow Extension

The large but mostly insignificant differences between MS and HS subjects and the isolated significant NS and TS difference appear likely to be caused by association of elbow extension measurement to body roll and lateral abduction of the shoulder. In swimmers of the caliber studied here, the forearm is rarely recovered over the top of the shoulder in a "windmilling" fashion. Therefore, swimmers with high lateral abduction of the shoulder will bend the elbow more to have a more efficient recovery. Since HS swimmers have higher lateral abduction, it follows that the HS swimmers will also have greater elbow bend. Conversely, swimmers with very low body roll cannot bend their elbows as much and must recover wider. MS swimmers have lower body roll measurements; therefore, they are also likely to have straighter elbows (greater elbow extension).

Conclusions

Measurements of maximum body roll and simultaneous lateral abduction of the shoulder were significantly different between swimmers whose shoulders are nonsymptomatic and those whose exhibit symptoms.
As a result, the null hypotheses relating to these two

biomechanical components were rejected, thus supporting the theory expressed by Richardson et al (28) that these factors increase the liklihood of impingement.

Measurements of elbow extension at mid-recovery were not consistently significantly different among swimmers of varying symptomatic levels. However, there were significant differences; therefore, the null hypothesis related to this component was rejected. The cause for the significant differences appear, however, to be more related to the biomechanics which affect the position of the upper and lower arm, particularly body roll and lateral abduction of the shoulder.

Impingement during recovery is consistent with the pattern of avascularity described by Rathbun and McNabb (27). Avascularity is very prominent at the adducted internally rotated position. This coincides with the position of the arm at the conclusion of the pulling phase and the initiation of recovery. As the shoulder is flexed and brought into the mid-recovery, intramuscular pressure would perpetuate the ischemic condition. Impingement during this period would be very likely to cause damage to the impinged tendons. Pain in shoulders was often associated with measurements on the opposite side. These results indicate that the cause for swimmer's shoulder pain may also be associated with an opposite arm reaction in the pulling arm. For example, lowered body roll is likely to result in a wider pulling pattern in the opposite arm, leading to increased lateral abduction in the pulling arm.

Moderate symptoms were strongly associated with lower body roll while severe symptoms were more strongly associated with lateral abduction. Since reduced body roll would contribute to increased lateral abduction, it appears feasible that increased problems with swimmer's shoulder are caused by reduced body roll and made worse as lateral abduction increases. The effects of body roll on opposite side arms may be very similar, with increased lateral abduction or some other factor, resulting from body roll, increasing shoulder problems. It is also possible that actions of the pulling arm are actually the initial link. Attempts to begin the catch early and keep the elbow high during the catch and initial part of the pulling phase may lead to decreased body roll and subsequently contribute to increased lateral abduction in the recovering arm.

The results of this study do not conclusively demonstrate any cause and effect relationship. Rather, the results only demonstrate that a relationship exists between body roll and simultaneous lateral abduction of the shoulder and that lowered body roll and increased lateral abduction of the shoulder are associated with increased symptoms of swimmer's shoulder.

Talented swimmers are affected more by swimmer's shoulder. This may be because the biomechanical compromises required for fast swimming put the swimmer at increased risk for impingement of the involved tendons. The emphasis on high elbows both during recovery and pulling may put swimmers who have a lower body roll at risk.

It seems that the best solution would be alteration of stroke mechanics to avoid the risks of swimmer's shoulder; however, these changes may have a negative impact on speed. Also, there may not be a satisfactory reciprocal effect on the pulling pattern. The pulling arm cannot be ruled out as a factor in shoulder pain or even as a major contributor to recovery mechanics observed in symptomatic swimmers in this study, nor can other biomechanical components be ruled out as contributors to swimmer's shoulder.

Those individuals training to be competitive swimming coaches must be made aware of possible injury prevention methods as an integral part of their education. The results of this study and any future studies providing insight into decreasing injury potentials are essential to the health of our athletes and subsequently to successful coaching.

The questions posed by the results of this study point toward the need for further research.

Recommendations

This study resulted in the acquisition of extensive data on the 76 subjects tested. Further analysis of the data may provide useful findings, particularly using incidences in various ranges of each of the biomechanical components.

The youngest swimmers in this study, the 13 year olds, demonstrated an incidence well below the other swimmers. Future research should limit the bottom age to 14 years.

There are a variety of biomechanical components which should be evaluated for potential relationships with swimmer's shoulder incidence. The following are some recommended areas for further investigation:

1. Underwater pulling phases. The use of simultaneous filming of underwater and above water biomechanics could provide useful insight into the relationship between recovery and opposite arm pulling.

2. Lateral shoulder abduction at all phases of the recovery.

3. Elbow extension at all phases of the recovery.

4. Relationships between shoulder flexibility and biomechanical components associated with increased incidence of swimmer's shoulder.

5. Multiple camera studies to determine relationships of angular velocities and trajectories on the incidence of swimmer's shoulder.

6. Evaluation of swimmers from overhead to evaluate cross over and hand placement.

7. Evaluation of timing for both body roll and breathing.

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APPENDICES

APPENDIX A

QUESTIONNAIRE

NAME: ______________________________________

TEAM: ______________ BEST STROKE: ______________

AGE: ____ SEX: ____

PICK THE NUMBER WHICH BEST DESCRIBES THE WAY YOUR SHOULDERS HAVE FELT WITHIN THE LAST YEAR:

0. NO PAIN.
1. A LITTLE PAIN NOW AND THEN, NO PROBLEM.
2. HURT PERIODICALLY AFTER PRACTICE.
3. HURT OFTEN DURING PRACTICE.
4. PAIN WAS ANNOYING FOR PERHAPS 8 HOURS A DAY AND COULD HAVE AFFECTED MY ABILITY TO PRACTICE HARD.
5. PAIN WAS VERY ANNOYING AND DEFINITELY AFFECTED MY ABILITY TO PRACTICE HARD.
6. HURT BAD, AT LEAST 12 HOURS PER DAY, UNLESS ICE OR MEDICATION WAS USED--ALMOST IMPOSSIBLE TO PRACTICE HARD.
7. IMPOSSIBLE TO TRAIN NORMALLY OR COMPETE--FORCED TO MISS SOME TRAINING OR COMPETITION.

LEFT SHOULDER: ______ RIGHT SHOULDER: ______

ID#:

APPENDIX B

SUMMARY OF INCIDENCES

Table 35. Incidence of Symptoms by Maximum Symptomatic Level by Team.

Team	n	%TS	%MS	%HS
LRD	20	40.0	25.0	15.0
UALR	7	28.6	14.3	14.3
CSC	27	37.0	22.2	14.8
KOKY	4	0.0	0.0	0.0
KHSBOY	6	16.7	0.0	16.7
KHSGIRL	6	16.7	0.0	16.7
KAT	2	0.0	0.0	0.0
WHS	4	0.0	0.0	0.0
TOTAL	76	28.9	16.7	13.2

APPENDIX B

Table 36. Incidence of Symptoms by Maximum Symptomatic Level by Stroke.

Stroke	n	%TS	%MS	%HS
Free	30	26.7	6.7	20.0
Fly	16	31.3	25.0	6.3
Back	15	26.7	20.0	6.7
Breast	12	33.3	25.0	8.3
IM	3	33.3	0.0	33.3
TOTAL	76	28.9	16.7	13.2

Table 37. Incidence of Symptoms by Maximum Symptomatic Level by Sex.

Sex	n	%TS	%MS	%HS
Male	36	30.6	16.7	13.9
Female	40	27.5	15.0	12.5
TOTAL	76	28.9	16.7	13.2

Appendix B

Table 38. Incidence of Symptoms by Maximum Symptomatic Level by Age.

Age	n	%TS	%MS	%HS
13	14	14.2	7.1	7.1
14	13	30.8	7.7	23.1
15	15	26.7	26.7	0.0
16	15	40.0	20.0	20.0
17	11	36.4	18.2	18.2
18+	8	25.0	12.5	12.5
TOTAL	76	28.9	16.7	13.2

APPENDIX B

Table 39. Incidence of Shoulder Symptoms--Body Roll (percentages rounded to the nearest .1)

		Left Shoulder			Right Shoulder		
B.*** Range	n	%TS	%MS	%HS	%TS	%MS	%HS
B.RB							
18-50	24	33.3	25.0	8.3	25.0	8.3	16.7
52-60	22	9.1	4.6	4.6	18.2	13.6	4.6
61-75	22	9.1	4.6	4.6	9.1	9.1	0.0
B.RNB							
15-33	19	31.6	21.1	10.5	31.6	21.1	10.5
34-44	20	20.0	10.0	10.0	10.0	10.0	20.0
46-66	21	4.8	0.0	4.8	4.8	0.0	4.8
B.LB							
32-43	13	38.5	23.1	15.4	38.5	15.4	23.1
44-56	15	26.7	6.7	20.0	20.0	20.0	0.0
57-74	14	0.0	0.0	0.0	7.1	0.0	7.1
B.LNB							
15-32	22	27.3	18.2	9.1	18.2	13.6	4.6
33-40	25	16.0	8.0	8.0	20.0	4.0	16.0
41-56	26	7.7	7.7	0.0	14.4	11.5	3.9

APPENDIX B

Table 40. Incidence of Shoulder Symptoms--Lateral Abduction (percentages rounded to the nearest .1)

		Left Shoulder			Right Shoulder		
A.***							
Range	n	%TS	%MS	%HS	%TS	%MS	%HS
A.RB							
-27 to -7	23	8.7	8.7	0.0	8.7	4.4	4.4
-6 to 1	23	4.4	4.4	0.0	13.0	13.0	0.0
2 to 23	22	40.9	22.7	18.2	31.8	13.6	18.2
A.RNB							
-14 to 1	22	4.6	4.6	0.0	4.6	4.6	0.0
2 to 9	19	5.3	0.0	5.3	10.5	5.3	5.3
10 to 34	19	47.4	26.3	21.1	42.1	21.1	21.1
A.LB							
-39 to -10	12	16.7	16.7	0.0	8.3	8.3	0.0
-9 to -5	15	6.7	6.7	0.0	13.3	6.7	6.7
-4 to 26	15	40.0	20.0	20.0	40.0	20.0	20.0
A.LNB							
-19 to -5	25	8.0	8.0	0.0	20.0	12.0	8.0
-4 to 1	23	13.0	13.0	0.0	13.0	4.4	8.7
2 to 25	25	28.0	12.0	16.0	20.0	12.0	8.0

APPENDIX B

Table 41. Incidence of Shoulder Symptoms--Elbow Extension (percentages rounded to the nearest .1)

		Left Shoulder			Right Shoulder		
E.*** Range	n	%TS	%MS	%HS	%TS	%MS	%HS
E.RB							
59-117	22	27.3	13.6	13.6	18.2	9.1	9.1
118-133	23	4.4	4.4	0.0	8.7	0.0	8.7
134-158	23	21.7	17.4	4.4	21.7	4.4	26.1
E.RNB							
54-113	20	15.0	0.0	15.0	10.0	0.0	10.0
115-137	19	20.1	15.8	5.3	26.3	10.5	15.8
139-174	20	20.0	15.0	5.0	20.0	20.0	0.0
E.LB							
71-129	15	33.3	20.0	13.3	26.7	6.7	20.0
130-141	13	7.7	0.0	7.7	23.2	15.4	7.7
142-171	13	15.4	15.4	0.0	7.7	7.7	0.0
E.LNB							
82-127	25	12.0	8.0	4.0	12.0	8.0	4.0
130-167	24	25.0	12.5	12.5	20.8	8.3	12.5
146-167	24	12.5	12.5	0.0	20.8	12.5	8.3

APPENDIX C

Raw Data

ID	PAIN.L	PAIN.R	B.RB	A.RB	E.RB	B.RNB	A.RNB	E.RNB
101	0	1	59	-5	110	0	0	0
102	1	1	64	-9	130	53	2	103
103	2	2	65	-8	118	0	0	0
104	4	2	50	8	113	0	0	0
105	1	3	52	-6	140	25	11	142
106	1	0	70	5	96	0	0	0
107	1	3	74	-4	88	0	0	0
108	1	5	55	6	120	28	34	115
109	1	1	38	0	144	39	3	144
111	2	2	43	-2	137	0	0	0
112	1	1	71	4	124	0	0	0
113	0	6	41	2	138	0	0	0
114	3	1	50	-4	135	0	0	0
115	1	1	68	9	119	66	0	110
117	0	1	53	2	128	51	-3	142
118	2	1	0	0	0	33	1	143
119	2	2	55	-13	127	46	0	139
120	1	1	64	1	111	56	5	107
121	0	3	49	4	141	0	0	0
122	1	7	46	18	119	0	0	0
201	0	7	0	0	0	46	16	110
202	1	1	75	-11	126	0	0	0
203	1	1	74	-2	100	0	0	0
204	0	1	71	-5	105	0	0	0
205	1	3	0	0	0	27	10	141
207	0	1	61	-13	142	30	-1	162
209	0	1	71	-11	144	0	0	0
301	1	0	55	4	112	38	-1	88
302	0	0	70	-5	64	61	9	54
303	1	1	61	1	85	55	9	103
304	1	1	72	1	122	48	3	113
305	0	1	0	0	0	44	4	0
306	1	1	57	-14	125	48	5	123
401	6	1	52	13	103	24	21	104
402	1	1	68	-4	100	39	2	109
403	1	0	60	-7	132	48	-5	111
404	2	2	44	-4	140	30	5	150
405	4	3	30	7	146	37	-4	154
406	4	3	61	-19	143	35	11	133
407	1	1	54	0	126	52	-2	133
408	1	2	38	1	142	37	1	137
409	1	1	55	-27	149	27	8	128

APPENDIX C

Raw Data

ID	PAIN.L	PAIN.R	B.LB	A.LB	E.LB	B.LNB	A.LNB	E.LNB
101	0	1	0	0	0	33	-5	152
102	1	1	61	-8	129	30	25	116
103	2	2	0	0	0	48	-9	130
104	4	2	0	0	0	54	-7	114
105	1	3	0	0	0	28	-10	152
106	1	0	0	0	0	42	2	113
107	1	3	0	0	0	48	4	97
108	1	5	0	0	0	33	-3	135
109	1	1	37	-2	139	37	-1	147
111	2	2	0	0	0	22	2	152
112	1	1	0	0	0	30	8	124
113	0	6	0	0	0	37	-18	152
114	3	1	0	0	0	19	12	152
115	1	1	74	-4	134	38	-1	140
117	0	1	60	-8	157	50	-4	142
118	2	1	57	-3	135	0	0	0
119	2	2	46	-23	153	37	-4	144
120	1	1	58	-9	147	55	-9	112
121	0	3	0	0	0	47	-19	133
122	1	7	0	0	0	34	2	150
201	0	7	59	-8	118	44	-5	125
202	1	1	0	0	0	34	-4	140
203	1	1	0	0	0	47	0	103
204	0	1	0	0	0	36	-8	145
205	1	3	46	-6	141	0	0	0
207	0	1	74	-39	131	50	-9	132
209	0	1	0	0	0	44	-11	121
301	1	0	59	-7	103	39	0	120
302	0	0	0	0	0	45	3	82
303	1	1	58	5	115	44	4	109
304	1	1	71	-1	94	52	-16	116
305	0	1	48	-5	119	52	-1	123
306	1	1	70	-11	134	48	11	145
401	6	1	55	3	94	34	10	135
402	1	1	62	0	105	56	2	107
403	1	0	37	-13	142	33	-10	148
404	2	2	40	-9	149	24	-1	167
405	4	3	39	4	129	36	-1	140
406	4	3	56	-21	155	44	-6	116
407	1	1	44	-7	133	29	-1	146
408	1	2	43	-7	143	30	-5	161
409	1	1	44	-22	158	29	-4	147

APPENDIX C

Raw Data

ID	PAIN.L	PAIN.R	B.RB	A.RB	E.RB	B.RNB	A.RNB	E.RNB
410	2	2	52	-12	127	46	-4	109
411	1	3	58	-4	137	33	3	174
412	1	1	0	0	0	42	-3	131
413	3	2	40	6	118	22	13	142
414	1	2	48	-6	127	47	-4	126
415	1	1	37	-7	146	37	1	135
416	1	1	30	7	149	33	4	144
417	4	5	47	-16	115	31	19	118
418	2	2	36	9	138	26	19	125
419	4	1	18	22	158	17	21	154
420	2	2	49	0	125	34	22	119
421	1	1	49	18	113	56	-3	101
422	1	1	52	-14	134	32	4	149
423	1	2	42	7	133	39	4	133
424	3	3	53	4	117	26	18	132
425	5	1	21	23	134	15	15	166
426	7	7	0	0	0	35	25	94
427	0	0	32	0	127	34	1	137
501	0	1	58	1	59	47	13	76
502	0	0	67	-12	114	58	-3	123
503	7	0	62	10	101	50	10	91
504	0	1	56	-8	81	46	10	100
505	2	2	71	-7	108	60	4	104
506	1	1	61	-7	120	41	2	135
507	1	1	43	-13	141	33	-4	145
508	1	1	52	-7	145	46	-14	145
509	1	1	0	0	0	28	4	151
510	2	2	56	-8	129	44	1	125
511	7	7	43	3	99	34	9	124
512	0	0	62	0	73	42	-4	112
513	0	0	52	-13	119	0	0	0
514	1	1	58	-9	118	44	3	108
515	1	1	0	0	0	43	-4	140
516	1	1	60	-5	148	35	21	140

APPENDIX C

Raw Data

ID	PAIN.L	PAIN.R	B.LB	A.LB	E.LB	B.LNB	A.LNB	E.LNB
410	2	2	44	-8	141	37	-15	143
411	1	3	50	-4	137	20	8	162
412	1	1	47	-4	141	50	-8	138
413	3	2	50	-13	120	28	12	130
414	1	2	0	0	0	41	-11	151
415	1	1	35	-10	147	33	-6	136
416	1	1	0	0	0	27	4	151
417	4	5	32	10	124	37	-3	133
418	2	2	0	0	0	19	8	145
419	4	1	46	-9	144	30	-2	157
420	2	2	0	0	0	34	6	112
421	1	1	0	0	0	41	1	112
422	1	1	46	-16	171	34	-1	144
423	1	2	44	-9	155	34	-2	153
424	3	3	37	5	0	15	18	145
425	5	1	0	0	0	25	13	140
426	7	7	38	26	122	0	0	0
427	0	0	43	-12	129	35	-8	115
501	0	1	64	-1	71	49	6	82
502	0	0	0	0	0	28	-7	161
503	7	0	0	0	0	40	16	119
504	0	1	0	0	0	32	2	124
505	2	2	0	0	0	45	6	90
506	1	1	0	0	0	48	-10	132
507	1	1	37	-7	141	33	-7	137
508	1	1	0	0	0	31	-4	160
509	1	1	43	-11	144	38	-2	140
510	2	2	0	0	0	30	-3	146
511	7	7	39	1	136	29	9	137
512	0	0	60	-11	130	36	4	121
513	0	0	0	0	0	30	-1	131
514	1	1	0	0	0	53	-14	127
515	1	1	53	-9	113	50	-11	135
516	1	1	0	0	0	38	-2	160

APPENDIX D

Subject Data

ID	TEAM	AGE	SEX	STROKE	PAIN.L	PAIN.R
101	LRD	14	M	FREE	0	1
102	LRD	17	F	BACK	1	1
103	LRD	17	M	FREE	2	2
104	LRD	17	M	BACK	4	2
105	LRD	17	M	FLY	1	3
106	LRD	14	M	FLY	1	0
107	LRD	16	M	FLY	1	3
108	LRD	16	M	FREE	1	5
109	LRD	16	F	FLY	1	1
111	LRD	13	F	BACK	2	2
112	LRD	15	F	FLY	1	1
113	LRD	17	M	FREE	0	6
114	LRD	15	F	BACK	3	1
115	LRD	15	F	FREE	1	1
117	LRD	17	F	BACK	0	1
118	LRD	15	M	BREAST	2	1
119	LRD	14	F	FLY	2	2
120	LRD	15	F	BACK	1	1
121	LRD	15	M	BREAST	0	3
122	LRD	16	F	FREE	1	7
201	UALR	18	M	FREE	0	7
202	UALR	20	M	IM	1	1
203	UALR	22	M	FREE	1	1
204	UALR	21	M	FREE	0	1
205	UALR	20	M	FREE	1	3
207	UALR	21	F	FLY	0	1
209	UALR	21	M	FREE	0	1
301	WHS	14	M	BACK	1	0
302	WHS	15	M	FREE	0	0
303	WHS	15	M	FLY	1	1
304	WHS	15	M	BACK	1	1
305	KAT	14	F	BREAST	0	1
306	KAT	13	M	FLY	1	1
401	CSC	17	F	BACK	6	1
402	CSC	16	M	FREE	1	1
403	CSC	15	F	BREAST	1	0
404	CSC	16	F	FREE	2	2
405	CSC	15	F	FLY	4	3
406	CSC	16	M	FLY	4	3
407	CSC	13	M	FREE	1	1
408	CSC	16	F	FLY	1	2
409	CSC	13	F	FREE	1	1

APPENDIX D

Subject Data

ID	TEAM	AGE	SEX	STROKE	PAIN.L	PAIN.R
410	CSC	14	F	BACK	2	2
411	CSC	15	F	BREAST	1	3
412	CSC	17	F	FREE	1	1
413	CSC	16	F	FREE	3	2
414	CSC	15	F	IM	1	2
415	CSC	16	F	FREE	1	1
416	CSC	13	F	BREAST	1	1
417	CSC	14	F	FREE	4	5
418	CSC	13	F	FREE	2	2
419	CSC	14	F	BACK	4	1
420	CSC	13	M	BREAST	2	2
421	CSC	16	M	FREE	1	1
422	CSC	13	F	FLY	1	1
423	CSC	13	F	BACK	1	2
424	CSC	13	F	BREAST	3	3
425	CSC	14	F	FLY	5	1
426	CSC	13	M	FREE	7	7
427	CSC	14	M	BACK	0	0
501	KHSBOY	16	M	BACK	0	1
502	KHSBOY	15	M	FREE	0	0
503	KHSBOY	16	M	BREAST	7	0
504	KHSBOY	14	M	BREAST	0	1
505	KHSBOY	18	M	BREAST	2	2
506	KHSGIRL	17	F	FLY	1	1
507	KHSGIRL	17	F	FREE	1	1
508	KHSGIRL	14	F	BACK	1	1
509	KHSGIRL	17	F	BREAST	1	1
510	KHSGIRL	15	F	FREE	2	2
511	KHSGIRL	14	F	IM	7	7
512	KHSBOY	16	M	FREE	0	0
513	KOKY	16	M	FREE	0	0
514	KOKY	13	F	FLY	1	1
515	KOKY	13	F	FREE	1	1
516	KOKY	13	M	FREE	1	1