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The Effect of Functional Training on the Incidence of Shoulder Pain and Strength in Intercollegiate Swimmers

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Scott M. Lephart, and Kellie Huxel

Objective: To determine whether functional training reduces the incidence of shoulder pain and increases strength in intercollegiate swimmers. **Design:** Pretest-posttest. **Setting:** Laboratory and weight room. **Participants:** 26 intercollegiate swimmers (13 men, 13 women). **Intervention:** 6-wk functional training program. **Main Outcome Measures:** Incidence of shoulder pain was recorded throughout the study. Isokinetic shoulder strength was assessed before and after training. **Results:** A *t* test showed significant differences ($P < .05$) for the incidence of shoulder pain between the experimental (mean episodes = 1.8 ± 2.1) and control (mean episodes = 4.6 ± 4.7) groups. ANOVA with repeated measures revealed no significant strength differences between groups but exhibited significant within-group increases. **Conclusions:** Incorporating functional exercises might reduce incidence of shoulder pain in swimmers. The results also validate the need to modify preventive programs as the demands of the sport change throughout the season. **Key Words:** functional rehabilitation, shoulder exercises, injury prevention

Swanik KA, Swanik CB, Lephart SM, Huxel K. The effect of functional training on the incidence of shoulder pain and strength in intercollegiate swimmers. *J Sport Rehabil.* 2002;11:140-154. © 2002 Human Kinetics Publishers, Inc.

"Swimmer's shoulder" is the most common orthopedic pathology in competitive swimmers, resulting in pain that interrupts training and performance.¹⁻⁸ Popularity in swimming at recent Olympic games has encouraged technical advances, improvements in conditioning, and the use of sophisticated training equipment, but increases in the level of competition and training have been linked to a concurrent rise in shoulder injuries.⁶

Kennedy and Hawkins⁹ first described the condition of swimmer's shoulder, not as a diagnosis but, instead, as a collection of symptoms that are consistent among competitive swimmers^{2,6} and resemble those of rotator-cuff tendinitis, subacromial bursitis, impingement syndrome, and instability.^{2,4,8-10} Several variables that could trigger the symptoms include shoulder flexibility, fatigue, improper technique, and strength imbalance.^{1,2,4,8,11}

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Functional Training Reduces Shoulder Pain in Intercollegiate Swimmers

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J. Reinsel

Functional training reduces the incidence of shoulder pain in intercollegiate swimmers. **Design:** Pretest–posttest. **Participants:** 26 intercollegiate swimmers (13 men) participated in a functional training program. **Main Outcome Measures:** Isokinetic strength was recorded throughout the study. **Results:** A *t* test showed no significant difference in the incidence of shoulder pain between the experimental and control (mean episodes = 4.6 ± 4.7). **Conclusions:** Functional training revealed no significant strength differences between groups and within-group increases. **Conclusions:** Incorporating functional training reduces the incidence of shoulder pain in swimmers. **Key Words:** functional rehabilitation, shoulder pain, strength, swimming.

Effect of functional training on the incidence of shoulder pain. *J Sport Rehabil.* 2002;11:140-154. © 2002 Human Kinetics

Shoulder pain is a common orthopedic pathology in competitive swimmers that interrupts training and performance. The incidence of shoulder pain at recent Olympic games has encouraged changes in conditioning, and the use of functional training has resulted in a significant increase in the level of competition. The concurrent rise in shoulder injuries has led to a re-evaluation of the condition of swimmer's shoulder pain, which is described as a collection of symptoms that are similar to those of rotator cuff impingement syndrome, and instability. The symptoms include shoulder pain, weakness, and strength imbalance.^{1,2,4,8,11}

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The treatment model for this pathology includes a decrease in yardage, anti-inflammatory medication, and modality treatments before and after practice.^{5,6,8,12} In most rehabilitative environments, this treatment protocol, with the addition of rotator-cuff strengthening, continues to be implemented and has been successful for relieving the symptoms of swimmer's shoulder.^{6,8,9} A limited amount of research, however, has investigated potential strategies for preventing the onset of this pathology.

Functional training is a component of most rehabilitation protocols that incorporates strength, endurance, agility, proprioception, and neuromuscular control—requirements that attempt to mimic the demands of a specific sport.^{13,14} Integrating functional exercises into a preventive training program could improve neuromuscular control and force-couple coactivation, as well as decrease the incidence of shoulder pathology, particularly in overhead sports such as swimming. To date, there is minimal information regarding specificity of functional training in relation to the incidence and prevention of shoulder pain. The purpose of this study was to determine whether functional training reduces the incidence of shoulder pain and increases shoulder strength in collegiate middle-distance and sprint swimmers.

Methods

Subjects

Twenty-six intercollegiate swimmers (13 men: height = 182.68 ± 6.10 cm, mass = 78.57 ± 8.16 kg; 13 women: height = 168.81 ± 13.13 cm, mass = 64.83 ± 8.26 kg) were randomly assigned to either a control or an experimental group. Subjects were included in this study if they had no limitations in swim and dry-land training as a result of shoulder pain and were excluded if classified as distance swimmers by their head coach or had had any previous surgeries to either shoulder. All subjects signed an informed consent approved by the university's institutional review board and completed a health-history questionnaire before participation.

Testing Procedures

A concentric shoulder-strength evaluation using the Biodex II Isokinetic Dynamometer (Shirley, NY) was administered on each subject's dominant extremity before and after a 6-week training period. All testing was completed during preseason training for the swimmers. The preseason training was required for all the athletes and included swim practice 6 d/wk and dry-land training 3 times/wk. The dry-land training involved upper and lower body weight training, lower extremity plyometrics, and cardiovascular conditioning and was supervised by the varsity coach and strength coach throughout the 6-week period.

Before testing, a warm-up of 5 submaximal repetitions was completed, followed by a 30-second rest period. Each maximal test consisted of 10 repetitions with a 90-second rest between tests. Isokinetic testing included internal and external rotation, scapular protraction and retraction, and a diagonal pattern. Internal and external rotation were performed in the seated position with the subject's arm in 90° of shoulder abduction and 90° of elbow flexion. Scapular protraction (serratus punch) and retraction were also performed in the seated position. The subject was instructed to protract and retract the scapula while maintaining full extension at the elbow. The diagonal pattern included reciprocal horizontal abduction / flexion and horizontal adduction / extension. The subject was instructed to perform the diagonal motion from a standing position while maintaining full elbow extension. All isokinetic tests were performed at speeds of 180° and 300°/s.¹⁵

Incidence of Injury

During the 6-week training period of the study, a certified athletic trainer recorded incidence of injury for the experimental and control groups. The incidence of injury was defined as pain that interfered with varsity practice and presented as a dull aching pain at night, pain while swimming, or a feeling of the shoulder being "tired." These subjects demonstrated a positive Neer's or Hawkins' test and required pain-management treatment and alterations in both dry-land and swim training. The athletes who presented with shoulder pain continued participating in all the lower extremity training and were instructed to kick with their arms at their side while in the pool. The functional program was resumed as soon as the athlete was pain free above 90° of shoulder abduction.

Functional Training Program

For the subjects randomly assigned to the experimental group, the functional training program was performed 3 days a week for 6 consecutive weeks and was supervised by a certified athletic trainer. The functional training program comprised 7 exercises; all were specifically designed for preseason swimming and were grouped as follows.

Elastic-Tubing Exercises. The first 4 exercises were performed for 3 sets of 10 repetitions with the subject in the standing position. Resistance for these exercises was provided by elastic tubing, beginning with the second level and progressing to subsequent levels when the subject was able to complete 3 sets of 10 repetitions with ease.

- *Internal and external rotation:* Internal and external rotation were executed in a functional position of 90° of shoulder abduction and 90° of elbow flexion (Figures 1 and 2). Each rotational direction was performed as a separate exercise to ensure equal concentric and eccentric resistance in both directions.

Figure 1 Inter

Figure 2 Ext



Figure 1 Internal-rotation exercise with elastic tubing.



Figure 2 External-rotation exercise with elastic tubing.

- *Horizontal abduction/flexion and horizontal adduction/extension:* Diagonal patterns of shoulder horizontal abduction / flexion (Figure 3) and horizontal adduction / extension (Figure 4) similar to the proprioceptive neuromuscular facilitation D2 flexion and extension patterns were done by the subjects.¹⁶ The abduction / flexion exercise began with the subject's shoulder in horizontal adduction and extension. The subject was instructed to flex and horizontally abduct the shoulder 180° and 140°, respectively. The horizontal adduction / extension exercise began with the shoulder at 180° of abduction and 140° of flexion, and the subject was instructed to horizontally adduct and extend his or her shoulder.

Prone Exercises. The prone-lying exercises were also performed in 3 sets of 10 repetitions. Free weights were used for resistance, beginning at 2 lb and increasing when the exercises could be performed without difficulty.

The fifth and sixth exercises were performed with the subject lying prone on a bench. The shoulder was positioned in 120° of abduction / external rotation for the fifth exercise. The subject was instructed to flex his or her shoulder while maintaining the abducted, externally rotated position (Figure 5).



Figure 3 Horizontal abduction/flexion exercise with elastic tubing, starting position.



Figure 4 Horizontal adduction/extension exercise with elastic tubing, starting position.



Figure 5 Prone exercise, external rotation with 120° abduction.

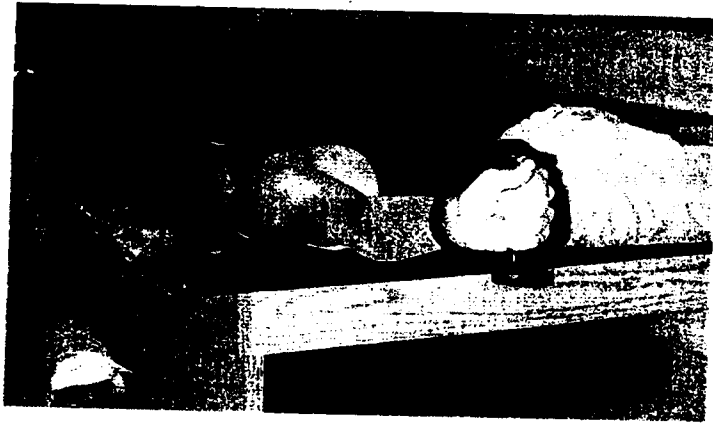


Figure 6 Prone exercise, external rotation with 90° abduction.

The sixth exercise was performed in the same manner but with the subject's shoulder in 90° of abduction (Figure 6).

Push-Up Plus. The push-up-plus exercise was performed in 3 sets, but each set was executed until fatigue. The subject was instructed to perform a traditional push-up with the hands placed shoulder-width apart. The "plus" component of the exercise required that the subject actively protract the scapula at the top of the push-up (after full elbow extension).

Statistical Analysis

Statistical analyses were performed using SPSS (SPSS Inc, Chicago, Ill). Data are reported as mean and standard errors (\pm SEM). A 2-tailed t test was used to compare the incidence-of-injury measures between the experimental and control groups. Two-way (Group \times Time) analyses of variance (ANOVAs) with repeated measures were performed to determine strength differences between the experimental and control groups after 6 weeks of swim and dry-land training at 180° and 300°/s during internal and external rotation, scapular protraction and retraction, and diagonal patterns. For all analyses, the level of significance was set at .05.

Results

Significant differences were revealed for the incidence of shoulder pain between the experimental and control groups ($t_{24} = 6.87$; $P = .02$, 2-tailed). The trained group had significantly less incidence of injury, averaging 1.8 (± 2.1) incidents, in comparison with the untrained group, which averaged

4.6 (± 4.7) incidents of shoulder pain over the course of the 6-week training session (Figure 7).

There were no significant strength differences ($P < .05$) identified between the groups for peak-torque to body-weight ratios at either 180° or 300°/s (Table 1 and Table 2). The results revealed significant within-group increases, however, in strength at 180°/s for internal rotation ($F_{1,24} = 17.47$, $P = .00$), horizontal abduction/flexion ($F_{1,24} = 21.31$, $P = .00$), horizontal

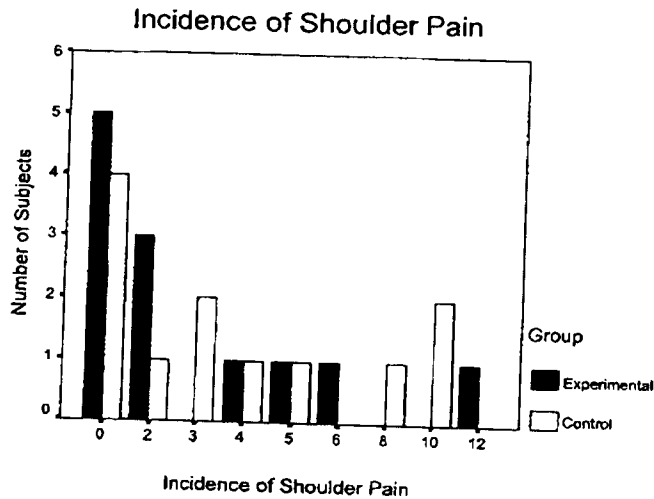


Figure 7 Incidence of injury.

Table 1 Peak Torque to Body Weight (180°/s)

Direction	Experimental Group		Control Group	
	Pretest	Posttest	Pretest	Posttest
Internal rotation*	14.34 \pm 8.43	19.20 \pm 8.30	16.01 \pm 4.41	18.95 \pm 7.30
External rotation	12.64 \pm 4.34	13.99 \pm 4.80	13.85 \pm 4.06	14.53 \pm 4.43
Horizontal abduction/flexion*	24.95 \pm 9.50	30.77 \pm 12.35	25.31 \pm 6.90	29.52 \pm 9.17
Horizontal adduction/extension*	30.07 \pm 13.74	34.62 \pm 11.30	33.85 \pm 8.27	36.04 \pm 8.72
Serratus punch*	9.18 \pm 4.69	11.54 \pm 4.32	9.80 \pm 4.10	11.55 \pm 4.10

* $P > .05$, significant difference.

Table 2 Peak Torque to Body Weight (300°/s)

Direction	Experimental Group		Control Group	
	Pretest	Posttest	Pretest	Posttest
Internal rotation*	15.22 ± 8.78	17.47 ± 6.02	16.06 ± 4.76	19.36 ± 6.02
External rotation	12.09 ± 3.97	12.60 ± 3.95	13.04 ± 3.93	12.92 ± 3.80
Horizontal abduction/flexion	25.46 ± 11.55	31.79 ± 10.93	30.64 ± 9.28	29.99 ± 13.80
Horizontal adduction/extension*	32.85 ± 15.39	40.91 ± 14.47	43.22 ± 13.76	44.87 ± 11.71
Serratus punch	9.01 ± 4.34	9.57 ± 3.01	9.12 ± 3.29	9.38 ± 3.24

**P* > .05, significant difference.

adduction/extension ($F_{1,24} = 7.45, P = .01$), and the serratus punch ($F_{1,24} = 23.26, P = .00$) for both the experimental and the control groups. No significant within-group differences were found at 180°/s for external rotation ($F_{1,24} = 4.23, P = .05$).

Statistically significant within-group differences were also revealed at 300°/s. Significant overall improvement in strength was demonstrated for internal rotation ($F_{1,24} = 7.06, P = .01$) and the diagonal pattern of horizontal adduction/extension ($F_{1,24} = 5.19, P = .03$). No significant within-group differences were revealed for the diagonal pattern of horizontal abduction/flexion ($F_{1,24} = 2.14, P = .16$), serratus punch ($F_{1,24} = 1.02, P = .32$), or external rotation at 300°/s ($F_{1,24} = 0.16, P = .70$).

Discussion

Forty percent to 80% of competitive swimmers have complaints of shoulder pain that interfere with training or competition, making it the most common orthopedic problem experienced by competitive swimmers.¹⁻⁸ The subjects in our study were all swimmers with a minimum of 6 years of competitive experience and were currently Division I varsity athletes. In order to examine a homogeneous population, middle-distance and sprint swimmers were included in this study because their dry-land- and swim-training requirements were the same. The subjects that presented with shoulder pain complained of a dull aching pain at night, sharp pain at either the beginning or the end of swim practice, pain when using swim paddles, or a feeling of the shoulder being "tired," symptoms that have been consistently defined in the literature as swimmer's shoulder.^{10,17,18} The findings in the present study revealed that the swimmers who completed

the functional training program experienced significantly fewer incidents of interfering shoulder pain than did the control group. The functional exercises used in this study did not result in significant strength increases between the groups. The reduction of interfering shoulder pain could be the result, however, of acquiring neuromuscular adaptations resulting in improved muscle efficiency.

Swimmer's shoulder has been linked to range of motion, improper technique, muscle fatigue, and strength imbalances. Swimmers typically present with an increase in external rotation and subsequent decrease in internal rotation when compared with normative data.^{1,8,19} This change in motion is thought to alter glenohumeral kinematics, predisposing the athlete to swimmer's shoulder and anterior instability.^{20,21} Greipp⁸ was able to predict swimmer's shoulder with 93% accuracy by assessing shoulder flexibility and found a significant correlation between anterior shoulder inflexibility and shoulder pain. Several other research studies, however, have not been able to identify a correlation between flexibility and shoulder pain.^{1,6,19}

Muscle fatigue has also been linked to the onset of swimmer's shoulder as a result of improper technique or a disruption in glenohumeral and scapulothoracic motions.⁶ Improper technique causes impingement symptoms by compromising vascularity, particularly at the entry phase of the stroke.^{6,9} Although uncommon in those performing at high levels of competition, a common technical mistake made by swimmers is "dropping the elbows" during the recovery phase of the stroke. This results in an increase in external rotation, placing unnecessary stress on the static stabilizers (ligaments and capsule) while fatiguing the dynamic stabilizers (rotator cuff, biceps, and scapular musculature) of the glenohumeral joint.²² Fatigue of the rotator cuff appears to decrease neuromuscular control, allowing for superior humeral-head migration and increasing the stress on both static and dynamic shoulder stabilizers. Saffran²³ documented the fact that with fatigue, a muscle's capacity to absorb energy is reduced, thus compromising dynamic joint stability. In swimming, this might alter scapulothoracic and glenohumeral mechanics, further predisposing the athlete to injury.^{13,14} Therefore, as the season progresses, exercises with an emphasis on endurance should be slowly introduced into the functional training program.

Glenohumeral- and scapulothoracic-strength developments and deficits have also been identified as contributing to swimmer's shoulder. Several studies have compared agonist:antagonist strength ratios for shoulder adduction/abduction and internal and external rotation in both upper extremity athletes and nonathletes. Although absolute strength was greater in athletes, the ratios were the same for both groups (2:1 for adduction/abduction and 3:2 for internal/external rotation).^{1,11,24-27} This study investigated exercises that replicated sport-specific positions and patterns and measured strength for internal and external rotation (at 90° of abduction and elbow flexion) and diagonal patterns of flexion/abduction and

extension/adduction. The diagonal patterns attempted to assess the "functional" strength of the glenohumeral and scapulothoracic musculature together and therefore were measured in multiplanar motions rather than true cardinal planes. The diagonal-pattern strength assessments did reveal increases in strength over time, which were attributed to the demands of swim training. Further investigation needs to be done, however, on the outcome of incorporating exercises in these functional positions throughout the course of a competitive season.

A 3:2 strength ratio has been established between internal and external rotation for upper extremity athletes and nonathletes.^{1,6,11,25,26,28,29} Shoulder-strength "imbalance" is thought to occur naturally as a result of a greater cross-sectional diameter of the internal rotator muscles, resulting in higher force output when compared with the external rotators.^{30,31} In addition, shoulder-torque ratio adaptations have been found to occur in athletes in upper extremity sports such as swimming, baseball, and water polo, indicating that the shoulder internal rotators and adductors are "superdeveloped" in comparison with the external rotators and abductors. These changes have been attributed to the repetitive demands placed on the shoulder over the course of a season and competitive swimming career that predispose the shoulder to muscle dysfunction.^{21,32-34}

There are limited data on shoulder-strength adaptations over time, making comparisons with previous studies difficult. To our knowledge, this is the first study to prospectively examine shoulder strength over 6 weeks of swim and dry-land training. Pretest internal to external shoulder-strength ratios were 1:1, indicating that the strength was balanced between the 2 muscle groups at 180° and 300°/s. After 6 weeks of training there was a significant increase in internal-rotation strength for both groups, at both speeds, without significant increases in external-rotation strength. The significant finding in internal-rotation strength resulted in the strength ratio moving closer to 3:2, supporting previous research.^{1,11} The lack of significant strength differences identified between groups could be the result of several factors. Typically, larger increases in strength are observed at the beginning of a training cycle than during the middle or at the end of a competitive season. Because this study took place during the preseason, both groups were involved in conditioning programs that required high resistance, eliciting strength gains that might have accounted for the lack of significant group differences. Therefore, the amount of weight or level of resistance used during the functional exercises was not enough to induce significant strength adaptations between groups. We believe that these exercises instead placed the shoulder in functional positions, with a resistance that facilitated more efficient muscle-firing sequences. Functional training might encourage force couples to work in concert and therefore improve joint protection. Synchronizing the force-couple activity will improve dynamic stability, minimize chronic microtrauma caused by unnecessary humeral-head translation, and, therefore, decrease the incidence of

shoulder pain. These results validate the need to modify the elements of the functional training program as the demands of swim training and competition progress throughout the season, placing emphasis on external-rotation strength and endurance of the glenohumeral and scapulothoracic musculature.

For optimal athletic performance, the dynamic stabilizers of the shoulder complex must fire in a consistent and coordinated fashion. Conditioning exercises should replicate the functional requirements associated with sport-specific skills.^{13,14} Unfortunately, most traditional weight-training programs fail to address the dynamic strength and endurance requirements of swimming, thus promoting shoulder dysfunction. Functional exercises were incorporated in daily dry-land training in this study in an attempt to target specific muscle groups in positions relative to the demands of the sport. Maximum recruitment of muscles responsible for humeral and scapular rotation and stabilization is necessary to provide dynamic stability of the glenohumeral joint and scapulothoracic articulation.^{13,14} Several researchers agree that exercises should be implemented in positions of vulnerability, thus inducing neural adaptations for dynamic restraint.^{13,14,21,35} Therefore, internal- and external-rotation exercises were implemented with the shoulder abducted to 90°. Combined movement patterns are believed to enhance force-couple coactivation and neuromuscular control, improving dynamic stability of the shoulder.¹³ For this reason, elastic-tube exercises in diagonal patterns of shoulder extension/adduction and shoulder flexion/abduction were included in the functional training program. Prone scapulation with external rotation at 90° and 120° was performed to maximize firing of the rotator cuff and scapular stabilizers.³⁶ The functional training program was initiated at the beginning of the swimmers' strengthening phase, and for this reason all tasks were implemented using 3 sets of 10 repetitions. Because endurance and strength are integral components of promoting and maintaining long-term dynamic stabilization, the push-up-plus exercise was performed until fatigue. This exercise also addressed glenohumeral and scapulothoracic control. The addition of the "plus" phase of the exercise initiated scapular protraction and serratus anterior strengthening while continuing to maintain joint compression throughout the exercise.^{13,14,37}

The results of this study indicate that functional training reduces the incidence of injury in swimmers. Strength changes did occur over a 6-week period, further validating the need to constantly reevaluate functional or dry-land training programs for strength and endurance developments and deficits, as well as to incorporate current demands of the sport throughout competitive and off-season programs. If the study were conducted just before or during the competitive season, we would suggest emphasizing the endurance component of the training by using higher repetitions and, possibly, lower resistance. Furthermore, decreasing or eliminating the amount of internal and adduction types of exercises and continuing to emphasize external rotation and abductor strength is recommended.

Conclusion

There was significantly less incidence of shoulder pain in the swimmers who participated in the functional training program than in the control group. Significant strength adaptations that occurred within the groups necessitate change in weight-training programs over the course of a competitive swim season. No significant strength differences were evident between groups. This study does support the importance, however, of incorporating functional strengthening exercises into swim-training regimens. These exercises performed at sport-specific angles and demands result in more efficient muscle-firing sequences, allowing for optimal joint protection and, therefore, decreasing the likelihood of the occurrence of swimmer's shoulder in this population.

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20th Annual Clinical Symposium

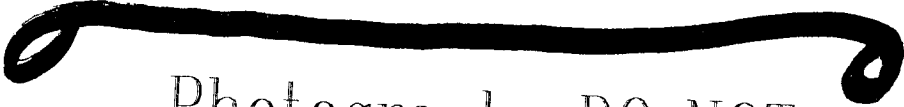
August 7-10, 2002

Hyatt Regency Crystal City

Washington, DC

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