Journal of Athletic Training 2016;51(1):65–69
doi: 10.4085/1062-6050-51.2.04

www.natajournals.org

Comparison of Upper Extremity Physical Characteristics Between Adolescent Competitive Swimmers and Nonoverhead Athletes

Elizabeth E. Hibberd, PhD, ATC*; Kevin Laudner, PhD, ATC†; David J. Berkoff, MD‡; Kristen L. Kucera, PhD, MSPH, ATC§; Bing Yu, PhD||; Joseph B. Myers, PhD, ATC§

*Department of Health Sciences, The University of Alabama, Tuscaloosa; †School of Kinesiology and Recreation, Illinois State University, Normal; ‡Department of Orthopaedics, §Department of Exercise and Sport Science, and ||Division of Physical Therapy, University of North Carolina at Chapel Hill

Context: Alterations to upper extremity physical characteristics of competitive swimmers (posture, range of motion [ROM], and subacromial-space distance) are commonly attributed to cumulative training load during a swimmer's competitive career. However, this accepted clinical belief has not been established in the literature. It is important to understand whether alterations in posture and associated physical characteristics occur as a result of sport training or factors other than swimming participation to better understand injury risk and possible interventions.

Objective: To compare posture, subacromial-space distance, and glenohumeral external-rotation, internal-rotation, and horizontal-adduction ROM between adolescent competitive swimmers and nonoverhead athletes.

Design: Cross-sectional study.

Setting: Local swimming pools and high school athletic training rooms.

Patients or Other Participants: Forty-four competitive adolescent swimmers and 31 nonoverhead athletes who were not currently experiencing any elbow, shoulder, neck, or back pain that limited their sport activity.

Intervention(s): Posture, subacromial-space distance, and glenohumeral ROM were measured using photography, diagnostic ultrasound, and a digital inclinometer, respectively.

Main Outcome Measure(s): Forward shoulder posture, forward head posture, normalized subacromial-space distance, internal-rotation ROM, and external-rotation ROM.

Results: No clinically significant differences existed between swimmers and nonoverhead athletes for posture, normalized subacromial-space distance, or external- or internal-rotation ROM. Swimmers presented with less horizontal-adduction ROM than nonoverhead athletes.

Conclusions: Factors other than swimming participation, such as school and technology use, play important roles in the adaptation of physical characteristics in adolescents. Adolescents, regardless of swimming participation, presented with postural deviations. It is important to consider factors other than swimming participation that contribute to alterations in physical characteristics to understand injury risk and injury-prevention strategies in competitive adolescent swimmers.

Key Words: subacromial space, range of motion, posture

Key Points

- Swimmers and nonoverhead athletes did not differ in posture, normalized subacromial-space distance, or rotational range of motion.
- Factors other than swimming participation, such as school and technology use, play important roles in the adaptation of physical characteristics.
- In addition to school, competitive swimmers are exposed to high levels of training, which may alter physical characteristics, increasing their risk of injury.

Currently more than 300 000 competitive club swimmers are active in the United States, and 43.5% of these members between the ages of 13 and 18 years are on elite teams.[1] Adolescent club swimmers complete 42 000 to 49 000 swimming yd per week (38 404 to 44 806 m) over 7 practices, in addition to dry-land and weight training.[2] Adolescent club swimmers train approximately 11 months of the year with only short breaks after competitions.[2] Because of this tremendous training load, shoulder pain is the most common musculoskeletal complaint in competitive swimmers.[3] Interfering shoulder pain has been reported in 45% to 91% of swimmers during their careers.[4,5] Shoulder pain in swimmers is a major cause of missed practices and slower swim times.[3]

Swimmers have anecdotally been described as having a forward head, rounded shoulders, and increased thoracic kyphosis, which can affect subacromial-space distance and glenohumeral range of motion (ROM).[6,7] The high volume of training over the swimmer's career is hypothesized to contribute to alterations in the observed physical characteristics of swimmers as the upper extremities adapt to the training demands. Although this

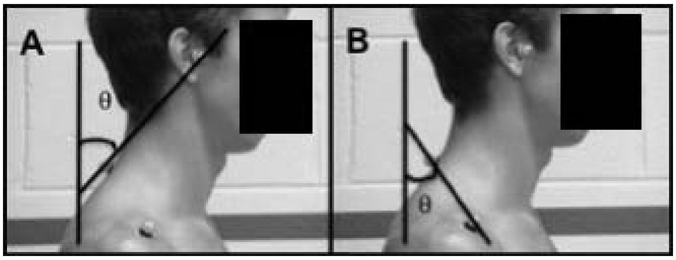

Figure 1. Posture assessment. A, Forward head angle. B, Forward shoulder angle.

theory has predominated in clinical practice, it has not been supported in the literature.

To date, researchers have not compared competitive swimmers with nonoverhead athlete controls for posture, subacromial-space distance, and glenohumeral ROM and to determine if deviations in these variables are due to factors other than swimming exposure. Alterations in posture, subacromial-space distance, and glenohumeral ROM may be present in both competitive swimmers and nonoverhead athletes because of factors other than swimming participation, such as computer use,[8] school desk design,[9] carrying a backpack,[10] and long study hours.[11]

Alterations in these physical characteristics and the demands placed on the shoulder during swim training may predispose swimmers to the development of *swimmer's shoulder*, a general term for overuse injury in swimming athletes, which includes subacromial impingement, rotator tendinosis, and biceps tendinosis.[4,5,12,13] It is important to understand whether alterations in posture and associated physical characteristics occur as a result of swim training or factors other than swimming participation to understand injury risk and possible interventions. Therefore, the purpose of this study was to compare posture, subacromial-space distance, and glenohumeral ROM between preseason competitive adolescent swimmers and nonoverhead athletes.

METHODS

Participants

Males and females between the ages of 13 and 18 years were recruited for a swimming group and a nonoverhead athlete group. Swimmers were included in the research study if they met all of the following criteria: senior (top training level) member of their club team, had at least 2 years of competitive swimming experience, regularly trained at least 4 times per week for 1 to 2 hours each session, and were not currently experiencing elbow, shoulder, neck, or back pain that limited their ability to participate. Nonoverhead athletes were recruited from local high schools and soccer, track, and cross-country leagues. Nonoverhead athlete participants were included in this research study if they had not been involved with an organized team of an overhead-dominant sport for more than 1 year and were not experiencing elbow, shoulder, neck, or back pain that limited activity during the course of the study.

Procedures

We used a cross-sectional research design with a competitive swimming group and a nonoverhead athlete group. All participants were evaluated 1 time before the start of the training season for competitive swimmers in mid-October. All participants and their parents or guardians read and signed the informed consent or assent form approved by a university institutional review board, which also approved the study; participants then underwent a physical examination that included evaluation of posture, subacromial-space distance, and glenohumeral ROM. All measures were assessed for the *dominant limb*, which was defined as the arm used to throw a ball for maximum distance. Although swimming is a bilateral motion, previous research[14] has indicated that swimmers maintain a dominant side because of handedness and developmental factors that carry over into their swimming stroke.

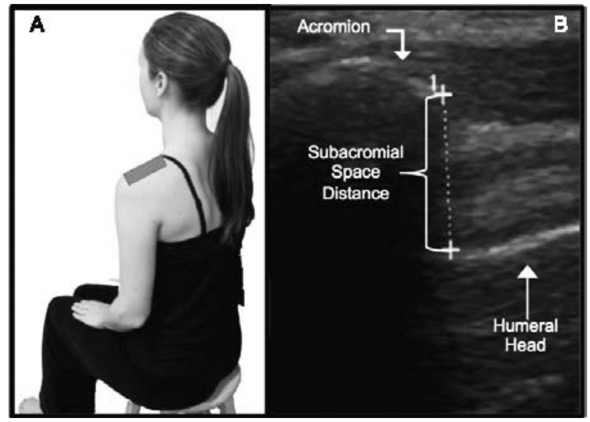

Figure 2. Measurement of subacromial-space distance. A, Participant positioning. B, Ultrasound measurement of subacromial-space distance.

We placed reflective markers on the C7 spinous process and the dominant-side tragus and anterior tip of the acromion.[15] Participants performed 3 overhead squats and then were instructed to stand in "a relaxed position" while a picture was taken in the sagittal plane. This procedure was repeated 2 additional times, for a total of 3 images to be analyzed. ImageJ software (National Institutes of Health, Bethesda, MD) was used to assess the postural variables. *Forward head angle* was defined as the angle of inclination of the line extending from C7 to the tragus and the vertical reference line (Figure 1A). *Forward shoulder angle* was defined as the angle of inclination of the line extending from C7 to the acromion and the vertical reference line (Figure 1B). A single investigator (E.E.H.) calculated the forward head and shoulder angles for each of 3 images and then a 3-trial mean. Before data collection, pilot testing was completed with 15 participants for all variables. Strong intrasession reliability and precision were demonstrated for forward head posture (intraclass correlation coefficient [ICC] = 0.98, SEM = 0.73°) and forward shoulder posture (ICC = 0.99, SEM = 0.9°)

Subacromial-space distance was measured using a portable diagnostic ultrasound machine (LOGIQe; General Electric, Milwaukee, WI). Each participant was assessed while seated in a chair with the forearm resting on the thigh. The ultrasound transducer was placed on the coronal plane of the shoulder (Figure 2A). The image was saved for analysis once the lateral acromion and humeral head could be visualized.[16] A blinded assessor (E.E.H.) measured subacromial-space distance using ImageJ software. *Sub-*

Figure 3. Range-of-motion assessment. A, Internal rotation. B, External rotation. C, Posterior shoulder tightness.

acromial-space distance was defined as the shortest distance between the anterior-inferior tip of the acromion and the superior humeral head (Figure 2B).[17] A 3-trial mean was calculated for each side. Average subacromial-space distance was normalized to height and presented as a percentage. Before data collection, strong intrasession reliability and precision were demonstrated for subacromial-space distance (ICC = 0.91, SEM = 0.04 cm).

Two examiners (research assistants who were not coauthors) passively measured glenohumeral internal- and external-rotation ROM with a digital inclinometer (model 01163; Lafayette Instrument Company, Lafayette, IN).[18] Participants lay supine with 90° of shoulder abduction and elbow flexion and scapular stabilization provided by the primary investigator. Scapular-stabilization force was provided by the primary investigator through a posteriorly directed force at the acromion to isolate motion at the glenohumeral joint. The primary investigator then passively rotated the limb to end range in internal rotation (Figure 3A) and external rotation (Figure 3B) while a research assistant aligned the inclinometer with the forearm and recorded the rotation angles. *End ROM* was defined as the point at which the primary investigator felt increased pressure from the acromion under the stabilizing hand.[19] A 3-trial mean was calculated. Before data collection, strong intrasession reliability and precision were demonstrated for measuring internal-rotation (ICC = 0.98, SEM = 1.4°) and external-rotation (ICC = 0.99, SEM = 1.2°) ROM.

Two examiners (research assistants who were not coauthors) assessed posterior shoulder tightness by measuring glenohumeral horizontal adduction with the participant lying supine (Figure 3C).[20] The scapula was stabilized in retraction and the humerus was elevated to 90° of abduction and neutral rotation and then passively horizontally adducted. At end range, a second examiner aligned the inclinometer with the midline of the humerus to measure the horizontal-adduction angle. A 3-trial mean was calculated. Before data collection, strong intrasession reliability and precision were demonstrated for measuring horizontal-adduction ROM (ICC = 0.91, SEM = 1.1°).

Table 1. Participant Demographics

Demographic	Swimmers (n = 44)	Nonoverhead Athletes (n = 31)
Females/males	26/18	21/10
	Mean ± SD	
Age, y	16.5 ± 1.0	16.5 ± 1.0
Height, cm	172.2 ± 12.9	168.8 ± 8.4
Mass, kg	66.2 ± 10.2	57.7 ± 8.2

Table 2. Posture Group Means, (Mean ± SD)

Posture	Swimmers	Nonoverhead Athletes
Forward head	36.1 ± 4.2	34.9 ± 4.0
Forward shoulder	45.1 ± 10.9	46.6 ± 8.5

Statistical Analysis

We calculated descriptive statistics for each variable. Independent *t* tests were performed to compare forward head posture, forward shoulder posture, normalized subacromial-space distance, and dominant-limb ROM between competitive swimmers and nonoverhead athletes. An a priori α level of .05 was set for all comparisons to determine statistical significance. All statistical analyses were performed using SPSS (version 20.0; SPSS Inc, Chicago, IL).

RESULTS

The study participants were 44 competitive adolescent swimmers and 31 nonoverhead athletes. Complete participant demographic information is provided in Table 1.

Mean forward head posture (P = .22) and forward shoulder posture (P = .60) did not differ between swimmers and nonoverhead athletes (Table 2). Normalized subacromial-space distance was similar between swimmers and nonoverhead athletes (P = .10; Table 3).

Dominant-limb glenohumeral horizontal-adduction ROM was different between swimmers and nonoverhead athletes ($t_{73} = 4.64$, $P < .001$; 95% confidence interval = 2.92, 7.33; Table 3). Swimmers presented with approximately 5.1° less dominant-limb horizontal-adduction ROM than nonoverhead athletes. Swimmers and nonoverhead athletes did not differ for dominant-limb internal-rotation ROM (P = .937) or external-rotation ROM (P = .709; Table 3).

DISCUSSION

Our findings indicate that during preseason measurement, few differences occurred between competitive swimmers and nonoverhead athletes. These findings have several implications for clinical practice. First, swimmers and nonoverhead athletes presented with similar alterations in forward shoulder posture at preseason measurements; therefore, contributors to forward shoulder posture other than repetitive overhead activity need to be identified. Second, these measures were taken during the swimmers' preseason; however, during the training season, swimmers perform a large volume of yardage with high-intensity practices to gain strength and power.[21] The tremendous training load that swimmers are exposed to may cause muscle fatigue and alterations in physical characteristics

Table 3. Dependent Variable Group Means (Mean ± SD)

Variable	Swimmers	Nonoverhead Athletes
Normalized subacromial space, % of height	1.2 ± 0.2	1.1 ± 0.1
Range of motion, °		
Internal rotation	55.5 ± 9.5	55.2 ± 6.9
External rotation	108.06 ± 12.3	109.1 ± 9.1
Horizontal adduction	18.9 ± 4.7	24.3 ± 4.4

that increase the risk of injury during the training season.[22] We chose this preseason time period as it is when most teams perform preparticipation screenings to identify those at risk of developing injury; yet serial examinations of physical characteristics may be needed to determine how the training load influences the athlete and increases the risk of injury.

Although no differences were evident between adolescent competitive swimmers and nonoverhead athletes for forward-head or forward-shoulder posture, both groups were above previously proposed criteria[15] for an ideal shoulder posture: equal to or less than 22° of forward shoulder angle. The swimmers demonstrated 45.1° and the nonoverhead athletes, 46.6°.

Forward-shoulder posture develops because of weakness of the posterior scapular stabilizers coupled with anterior musculature contracture. Other than repetitive overhead activity, lifestyle factors such as computer use,[8] school desk design,[9] carrying a backpack,[10] and long study hours[11] may contribute to poor posture in the student population. Laptop computers increase exposure to risk factors for musculoskeletal disorders because of their compact size, integrated monitors, and less than ideal input devices.[23,24] To view the computer screen, individuals assume a more forward shoulder and head posture.[11] Over time, this posturing during computer use may lead to adaptations in shoulder physical characteristics and increase the risk of injury. In addition, it has been suggested that school desks are not ergonomically advantageous,[9] as students must adjust their posture to read paper documents and notes that are sitting on their flat desks. Recent suggestions[11,24] to improve students' sitting posture include adjustable desk heights and angled desks. Based on our results, all adolescents should focus on improving forward shoulder posture. This could be done through a strengthening and stretching program in physical education class to address muscular imbalances, improve computer and desk ergonomics, and increase education on the importance of good posture.

Swimmers presented with increased posterior shoulder tightness, represented by less horizontal adduction, compared with nonoverhead athletes. The repetitive nature of swimming may fatigue the posterior rotator cuff and periscapular muscles, which may place more stress on the posterior capsule to maintain joint stability through the swimming stroke.[25] Over time, the distractive stress may cause repetitive microtrauma to the posterior capsule and a fibroblastic healing response that results in hypertrophy and contracture. As athletes with posterior shoulder tightness move into abduction with external rotation (as seen in the recovery phase of the swimming stroke[26]), superior-posterior translation of the humeral head may increase.[27] This abnormal translation can decrease the subacromial distance and compress the structures within the subacromial space during dynamic movements. It may be beneficial to address the posterior shoulder tightness of swimmers to allow the humeral head to remain centered during dynamic activity, which may help to prevent impingement during the swimming motion. Potential treatments to improve posterior shoulder tightness include stretching exercises to address muscle flexibility,[28,29] joint mobilization to address capsular tightness,[30] and other forms of manual therapy[31] to address neuromuscular abnormalities.

Limitations of the current study need to be addressed. We may not have observed alterations in subacromial distance because assessments were taken during a static posture. Abnormal narrowing of the subacromial space may be present if the assessment is done during a dynamic task. Also, the physical characteristics were assessed before the start of the training season. Previous authors have identified adaptations in scapular kinematics that may promote shoulder impingement over the course of the first 6 weeks of the training season in collegiate swimmers[22] and after a fatigue protocol.[32] The timing of the assessment may have influenced the results.

Future researchers should focus on how the physical characteristics of swimmers (posture, glenohumeral ROM, and subacromial-space distance) change over the course of the training season, as well as how physical characteristics change because of participation variables, to better understand injury risk during the training season. In addition, future investigations of swimmers and other overhead athletes should include lifestyle factors, such as time on laptop computers and other devices and posture at school, to understand the roles of these lifestyle factors in the development of shoulder pain and injury in overhead athletes.

CLINICAL SIGNIFICANCE

Lifestyle factors, such as school and technology use, play an important role in the adaptation of physical characteristics. In addition to school, competitive swimmers are exposed to high levels of training that might further exacerbate any alterations in physical characteristics. These findings highlight the importance of interventions during the school day and personal time to improve posture, as well as strengthening and stretching programs to decrease the risk of shoulder injury in competitive swimmers.

ACKNOWLEDGMENTS

This research study was funded by the NATA Research & Education Foundation (grant 13DGP004).

REFERENCES

1. 2012 USA Swimming membership demographics. USA Swimming Web site. http://www.usaswimming.org/_Rainbow/Documents/ceb07df5-c623-49a9-ad4c-dc331707b3a4/Statistics-2012.pdf. Published 2012. Accessed January 14, 2014.
2. Hibberd EE, Myers JB. Practice habits and attitudes and behaviors concerning shoulder pain in high school competitive club swimmers. *Clin J Sport Med*. 2013;23(6):450–455.
3. Weldon EJ III, Richardson AB. Upper extremity overuse injuries in swimming: a discussion of swimmer's shoulder. *Clin Sports Med*. 2001;20(3):423–438.
4. Pink MM, Tibone JE. The painful shoulder in the swimming athlete. *Orthop Clin North Am*. 2000;31(2):247–261.
5. Sein ML, Walton J, Linklater J, et al. Shoulder pain in elite swimmers: primarily due to swim-volume-induced supraspinatus tendinopathy. *Br J Sport Med*. 2010;44(2):105–113.
6. Kebaetse M, McClure P, Pratt NA. Thoracic position effect on shoulder range of motion, strength, and three-dimensional scapular kinematics. *Arch Phys Med Rehabil*. 1999;80(8):945–950.
7. Kluemper M, Uhl TL, Hazelrigg H. Effect of stretching and strengthening shoulder muscles on forward shoulder posture in competitive swimmers. *J Sport Rehabil*. 2006;15(1):58–70.

8. Harris C, Straker L. Survey of physical ergonomics issues associated with school childrens' use of laptop computers. *Int J Ind Ergonom*. 2000;26(3):337–346.
9. Yeats B. Factors that may influence the postural health of schoolchildren (K–12). *Work*. 1997;9(1):45–55.
10. Devroey C, Jonkers I, de Becker A, Lenaerts G, Spaepen A. Evaluation of the effect of backpack load and position during standing and walking using biomechanical, physiological and subjective measures. *Ergonomics*. 2007;50(5):728–742.
11. Asundi K, Odell D, Luce A, Dennerlein J. Notebook computer use on a desk, lap and lap support: effects on posture, performance and comfort. *Ergonomics*. 2010;53(1):74–82.
12. Bak K, Magnusson SP. Shoulder strength and range of motion in symptomatic and pain-free elite swimmers. *Am J Sports Med*. 1997; 25(4):454–459.
13. Richardson AR. The biomechanics of swimming: the shoulder and knee. *Clin Sports Med*. 1986;5(1):103–113.
14. Sanders RH, Thow J, Fairweather M. Asymmetries in swimming: where do they come from? *J Swimming Res*. 2011;18:1–11.
15. Thigpen CA, Padua DA, Michener LA, et al. Head and shoulder posture affect scapular mechanics and muscle activity in overhead tasks. *J Electromyogr Kinesiol*. 2010;20(4):701–709.
16. Wang HK, Lin JJ, Pan SL, Wang TG. Sonographic evaluations in elite college baseball athletes. *Scand J Med Sci Sports*. 2005;15(1): 29–35.
17. Michener LA, Subasi Yesilyaprak SS, Seitz AL, Timmons MK, Walsworth MK. Supraspinatus tendon and subacromial space parameters measured on ultrasonographic imaging in subacromial impingement syndrome. *Knee Surg Sports Traumatol Arthrosc*. 2015;23(2):363–369.
18. Norkin CC, White DJ. *Measurment of Joint Motion: A Guide to Goniometry*. 2nd ed. Philadelphia, PA: FA Davis; 1995.
19. Hibberd EE, Oyama S, Tatman J, Myers JB. Dominant-limb range-of-motion and humeral-retrotorsion adaptation in collegiate baseball and softball position players. *J Athl Train*. 2014;49(4):507–513.
20. Myers JB, Oyama S, Wassinger CA, et al. Reliability, precision, accuracy, and validity of posterior shoulder tightness assessment in overhead athletes. *Am J Sports Med*. 2007;35(11):1922–1930.
21. Salo D, Riewald S. *Complete Conditioning for Swimming*. Champaign, IL: Human Kinetics; 2008.
22. Hibberd EE, Oyama S, Spang JT, Prentice W, Myers JB. Effect of a 6-week strengthening program on shoulder and scapular-stabilizer strength and scapular kinematics in Division I collegiate swimmers. *J Sport Rehabil*. 2012;21(3):253–265.
23. Chang CH, Amick BC, Menendez CC, Robertson MM, Dennerlein JT. Where and how college students use their laptop computers. *Proc Human Factors Ergon Soc Annu Meet*. 2008;52(15):1010–1014.
24. Koskelo R, Vuorikari K, Hanninen O. Sitting and standing postures are corrected by adjustable furniture with lowered muscle tension in high-school students. *Ergonomics*. 2007;50(10):1643–1656.
25. Su KP, Johnson MP, Gracely EJ, Karduna AR. Scapular rotation in swimmers with and without impingement syndrome: practice effects. *Med Sci Sport Exerc*. 2004;36(7):1117–1123.
26. Yanai T, Hay JG. Shoulder impingement in front-crawl swimming, II: analysis of stroking technique. *Med Sci Sports Exerc*. 2000;32(1): 30–40.
27. Clabbers KM, Kelly JD, Bader D, et al. Effect of posterior capsule tightness on glenohumeral translation in the late-cocking phase of pitching. *J Sport Rehabil*. 2007;16(1):41–49.
28. Laudner KG, Sipes RC, Wilson JT. The acute effects of sleeper stretches on shoulder range of motion. *J Athl Train*. 2008;43(4):359–363.
29. Oyama S, Goerger CP, Goerger BM, Lephart SM, Myers JB. Effects of non-assisted posterior shoulder stretches on shoulder range of motion among collegiate baseball pitchers. *Athl Train Sports Health Care*. 2010;2(4):163–170.
30. Cools AM, Cambier D, Witvrouw EE. Screening the athlete's shoulder for impingement symptoms: a clinical reasoning algorithm for early detection of shoulder pathology. *Br J Sports Med*. 2008; 42(8):628–635.
31. Tyler TF, Nicholas SJ, Lee SJ, Mullaney M, McHugh MP. Correction of posterior shoulder tightness is associated with symptom resolution in patients with internal impingement. *Am J Sports Med*. 2010;38(1):114–119.
32. Ebaugh DD, McClure PW, Karduna AR. Effects of shoulder muscle fatigue caused by repetitive overhead activities on scapulothoracic and glenohumeral kinematics. *J Electromyogr Kinesiol*. 2006;16(3): 224–235.

Address correspondence to Elizabeth E. Hibberd, PhD, ATC, Department of Health Sciences, The University of Alabama, 483 Russell Hall, Box 870311, Tuscaloosa, AL 35487-0311. Address e-mail to eehibberd@ches.ua.edu.