
CHARACTERISTICS OF SHOULDER IMPINGEMENT IN THE RECREATIONAL WEIGHT-TRAINING POPULATION

MOREY J. KOLBER,¹ SCOTT W. CHEATHAM,² PAUL A. SALAMH,³ AND WILLIAM J. HANNEY⁴

¹Department of Physical Therapy, Nova Southeastern University, Fort Lauderdale, Florida; ²Division of Kinesiology and Recreation, California State University, Carson, California; ³Southeastern Orthopedics Physical Therapy, Raleigh, North Carolina; and ⁴University of Central Florida, Program in Physical Therapy, Orlando, Florida

ABSTRACT

Kolber, MJ, Cheatham, SW, Salamh, PA, and Hanney, WJ. Characteristics of shoulder impingement in the recreational weight-training population. *J Strength Cond Res* 28(4): 1081–1089, 2014—Despite reports implicating subacromial impingement syndrome (SIS) as an etiologic source of shoulder pain among weight-training (WT) participants, a paucity of case-controlled evidence exists to support this premise. The purpose of this study was to determine whether WT participants present with characteristics of SIS. Additionally, we investigated the role of exercise selection among those identified as having SIS. Seventy-seven (154 shoulders) men (mean age, 28) were recruited, including 46 individuals who engaged in WT a minimum of 2 days per week; and 31 controls with no history of WT participation. Before testing, participants completed a questionnaire summarizing their training patterns. On completing questionnaire, 2 previously validated tests used to identify SIS were performed on both groups and included the painful arc sign and Hawkins-Kennedy test. When clustered, these tests have a positive likelihood ratio of 5.0 for identifying SIS when compared with diagnostic gold standards. Analysis identified significant between-group differences in the combined presence of a positive painful arc and Hawkins-Kennedy ($p < 0.001$) test. A significant association existed between clinical characteristics of SIS ($p \leq 0.004$) and both lateral deltoid raises and upright rows above 90°. Conversely, a significant inverse association was found between external rotator strengthening and characteristics of SIS. Results suggest that WT participants may be predisposed to SIS. Avoiding performance of lateral deltoid raises and upright rows beyond an angle of 90° and efforts to strengthen the external rotators may serve as a useful means to mitigate characteristics associated with SIS.

KEY WORDS Hawkins-Kennedy test, painful arc, rotator cuff, subacromial impingement

Address correspondence to Morey J. Kolber, kolber@nova.edu.

28(4)/1081–1089

Journal of Strength and Conditioning Research

© 2014 National Strength and Conditioning Association

INTRODUCTION

It has been reported that more than 45 million Americans participate in some form of resistance training regularly (6). The Centers for Disease Control analyzed data from the National Health Interview Survey to determine the prevalence of strength training in the adult population from 1998 to 2004 and estimated that nearly 20% of adults between the ages of 18 and 65 years participate in some form of resistance training 2 or more times a week (6). Weight training (WT) has been advocated as a means of developing musculoskeletal performance for sports (12), rehabilitation of injuries (2,10), and for various health and fitness benefits (1,11,38). Although the health and performance benefits ascribed to WT are well documented, the pursuit of these benefits has not been without risk given that a considerable number of WT related injuries have been reported in the literature (14,23,24,27,35,36).

The shoulder complex accounts for a considerable proportion of injuries attributed to WT (4,7,13,14,17,18,21,27,32,35,36). Researchers have reported that up to 36% of injuries in the WT population occur within the shoulder complex (14,24,27,30) with the range of injuries being classified along the spectrum from acute to chronic disorders that manifest as pain or impairments that interfere with training.

The susceptibility of the shoulder complex to injury is partly due to the stress WT places on the shoulder joints, requiring a non-weight-bearing joint to assume the role of weight bearing during the course of repetitive lifting while under heavy loads. Furthermore, it has been postulated that WT routines emphasize large muscles that produce obvious gains in strength and hypertrophy, subsequently neglecting the muscles responsible for stabilization such as external rotators (3). Normal shoulder function requires a delicate balance between mobility and strength of muscle groups that function synchronously during activities. Training routines that are biased toward specific muscle groups or exercises often neglect the required strength and mobility balance necessary for unimpaired shoulder function.

Although the underlying etiology of shoulder pain among WT participants is multifactorial, subacromial impingement syndrome (SIS) is often implicated (25,37). Various factors

are thought to predispose an individual to SIS (impingement of the soft tissues, namely rotator cuff tendons and bursa, between the bony structures of the shoulder during elevation) and include the aforementioned muscle imbalances, training patterns that have biased muscle recruitment, and WT exercises (8,25,37) that place the shoulder in biomechanically incorrect positions. A specific example of this can be seen with WT exercises that require abduction (elevation) of the arm above shoulder height when the arm is internally rotated (Figure 1). Abduction of the arm biomechanically requires external rotation of the humerus to avoid SIS (28), and evidence exists to suggest that abduction of the arm while internally rotated causes SIS, with the 90° position producing the greatest degree of impingement (15,16). Essentially, the combination of repetitive loading while in a biomechanically unfavorable position, as seen with lateral deltoid raises (Figure 1) and upright rows (Figure 2) when performed to an angle of 90° (shoulder level) or greater, may lead to or perpetuate SIS.

Although individuals with SIS may be asymptomatic with general function, activities such as WT place greater demands on the shoulder, thus pain during participation may provide insight into underlying symptomatically occult pathologies. Moreover, identification of this is clinically important as evidence suggests a clear link between SIS and both rotator cuff pathology and bursitis (29,34).

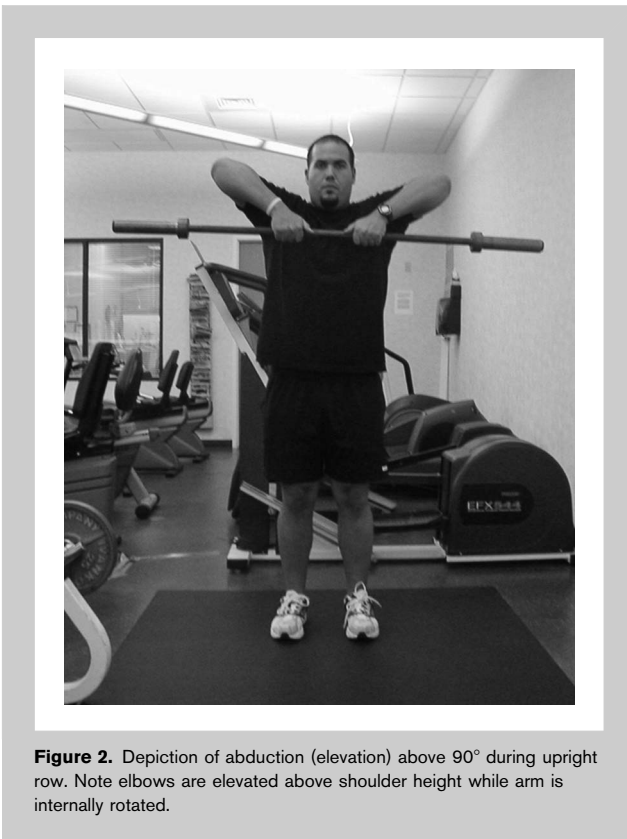


Figure 2. Depiction of abduction (elevation) above 90° during upright row. Note elbows are elevated above shoulder height while arm is internally rotated.

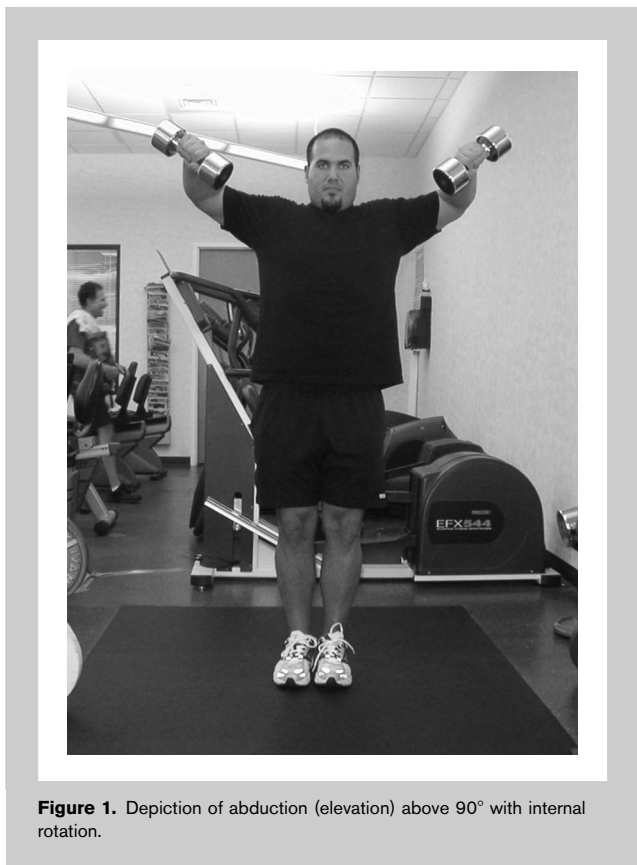


Figure 1. Depiction of abduction (elevation) above 90° with internal rotation.

The purpose of this study was to determine whether men who participate in WT present with characteristics of SIS based on the results of a validated diagnostic testing cluster. Additionally, we sought to determine if there is a significant difference between the presence of SIS among WT participants when compared with a control group with no history of WT participation or upper extremity sports. Finally, we set out to investigate the association of exercise selection with clinical characteristics of SIS. To our knowledge, there are no previous investigations that have compared the presence of SIS in the WT population to a control group. Moreover, a paucity of research exists beyond case reports to identify at-risk training patterns that may be associated with SIS. Evidence-based identification and recognition of at-risk training patterns is essential for the strength and conditioning professional and other professionals involved in the prescription of WT exercises.

METHODS

Experimental Approach to the Problem

This investigation was a descriptive analysis of the shoulders of men who participate in WT with a control group comparison. The independent variables were group assignment, which consisted of the WT and control group. The dependent variables measured to describe the characteristics of SIS were the painful arc sign and the Hawkins-Kennedy test. A questionnaire was provided to participants to

document their specific training patterns that included frequency, presence of pain, and exercise selection. Specifically, participants were asked whether they performed certain exercises deemed to be high risk for injury based on descriptive epidemiological reports. We sought to determine whether there was a relationship between exercise selection and clinical characteristics of SIS.

Subjects

Institutional review board approval was obtained before commencing recruitment. All participants completed a Nova Southeastern University Institutional Review Board approved informed consent before participation. Seventy-seven participants (154 shoulders) of age 19–56 years (mean age, 28 ± 6.5 years) were recruited from a University setting and local fitness centers over a 3-year duration. Participants included 46 individuals who participated in recreational upper extremity WT at a frequency of 2–5 days per week (mean, 3 days) with WT experience before data collection ranging from 12 weeks to 30 years (mean, 9 years). Thirty-one individuals who did not perform any upper extremity WT or competitive upper extremity dominant sports served as controls for this study. Participants were surveyed on the type of upper-body exercises that they routinely performed as part of their WT program. All of the WT participants recruited for this study reported performing at least 3 or more of the following exercises as part of their routine: (a) flat bench press, (b) incline bench press, (c) chest flies (supine or incline), (d) military press (dumbbells or barbells), (e) behind-the-neck latissimus dorsi pull-downs, (f) upright rows, and (g) lateral deltoid raises. Nine of the 46 WT participants reported either having their program designed by a professional who is certified or licensed to prescribe exercise programs (personal trainer, certified strength and conditioning specialist, athletic trainer, or physical therapist) or being certified or licensed themselves. None of the participants reported having their program currently supervised by a credentialed professional.

Participants were excluded if they participated in professional bodybuilding, competitive powerlifting or weightlifting, or competitive overhead sports. Additionally, participants with a history of shoulder surgery or current participation in a formal shoulder rehabilitation program were excluded because we believed this would bias exercise

selection. Participants in the WT group were surveyed regarding the presence of shoulder pain during WT in the past year and in the past 72 hours. Additionally, the control group was surveyed for the presence of shoulder pain in the past 72 hours. None of the control group participants reported pain in the past 72 hours. The time frame of 72 hours was chosen because we wanted to capture a period that would have included at least 1 upper extremity training session. Seventy-four percent of WT participants reported shoulder pain during the course of training in the past year, whereas 26% reported pain during the past 72 hours. Statistical analysis revealed no significant differences ($p \geq 0.16$) between the WT and control groups for the variables of age, mass, height, and body mass index (Table 1).

Procedures

Testing was performed in an air-conditioned facility, and all participants from the WT group had not trained the day of testing. Testing was routinely carried out between 12:00 PM and 7:00 PM. Standardized warm-up exercises were completed by all participants before testing. Warm-up consisted of the pendulum exercise performed both clockwise and counterclockwise for 10 repetitions each and standing scapular adduction without resistance performed with a 10-second hold for 10 repetitions. The warm-up lasted approximately 3 minutes and was not intended to influence symptoms in any manner. The principal investigator (M.K.), a licensed physical therapist with 15-year clinical experience and a specialist certification in orthopedics performed all tests. A trained assistant recorded all findings on a data collection

TABLE 1. Demographic characteristics of participants.

Characteristics	Total (77)	Control (31)	WT (46)	<i>p</i>
Age (y)				
Mean (SD)	28.3 (6.5)	29.0 (6.1)	27.9 (6.9)	0.46*
95% CI†	26.8–29.8	26.8–31.2	25.9–29.9	
Range	37	23	35	
Mass (kg)				
Mean (SD)	87.2 (9.6)	86.1 (11.1)	88.0 (8.4)	0.41*
95% CI	85.1–89.4	82.1–90.2	85.5–90.5	
Range	61.4	61.4	37.3	
Height, cm				
Mean (SD)	178.0 (6.1)	178.8 (6.3)	177.6 (6.0)	0.39*
95% CI	176.7–179.4	176.5–181.1	175.8–179.3	
Range	35.6	33.0	22.9	
Body mass index				
Mean (SD)	27.5 (3.0)	26.9 (3.3)	27.9 (2.7)	0.16‡
95% CI	26.8–28.1	25.7–28.1	27.1–28.7	
Range	17.0	17.0	10.6	

*Independent *t*-test.
 †CI = confidence interval.
 ‡Mann-Whitney *U*-test.

sheet, which the investigator was blinded to during data collection. The investigator was not blinded to group assignment. Testing was initiated in the same order for each participant with the painful arc sign first followed by the Hawkins-Kennedy test. Both tests were performed bilaterally.

Painful Arc Sign. This test is designed to detect SIS and has previously been reported to have intertester agreement of 73–74% (31,33) when performed in a manner similar to this study. Given the absence of intrarater data in the literature, a pilot intrarater assessment was performed by the principal investigator on 20 shoulders of individuals participating in this study with the agreement of 95%. A trained assistant recorded results from the intrarater reliability trial and coordinated participants in a nonsequential order as a means to minimize recall bias.

The test was carried out with participants in a seated position in a chair with a high back to prevent trunk extension. The investigator first demonstrated active abduction of the humerus in the coronal plane with the arm in neutral to slight external rotation (thumb up). The participant was then asked to perform the same motion previously demonstrated by the investigator, first for the nondominant arm followed by the dominant arm. Before performing the movement actively, participants were requested to notify the investigator if pain was perceived at any point during the movement. If pain was reported, the participant was asked to repeat the movement one additional time and advise the investigator immediately on experiencing pain within their range. The interpretation of what constitutes a positive test has varied; however, we used similar criteria as previously described within validity investigations (31,34). Specifically, a positive test was recorded when the participant reported a feeling of pain or catching at the anterior or lateral shoulder between the ranges of approximately 60–140° abduction. While the aforementioned studies used 60–120°, we used the range of 60–140° given that impingement has been reported to occur within this range (15,16,22,28,34). The overall accuracy of the painful arc sign for identifying SIS has been reported at 76% (34). Pooled meta-analysis suggests that the painful arc sign has a positive likelihood ratio of 2.25 when the results are analyzed independent of other tests (20).

Hawkins-Kennedy Test. This test is used to diagnose SIS and has reported intertester agreement values of 68–69% (5,31) when the test is performed similar to the procedure used in this investigation (Figure 3). Given the absence of intrarater data in the literature, a pilot intrarater assessment was performed by the principal investigator on 20 shoulders of individuals participating in this study with the agreement of 100%.

The test is performed with the participant seated on a plinth with no trunk support. The investigator places and holds the participants arm in 90° forward flexion (sagittal



Figure 3. Hawkins-Kennedy test. Investigator brings tested arm into 90° flexion and applies internal rotation through elbow contact.

plane) and then gently and slowly through contact with the elbow internally rotates the arm. The elbow is kept at 90° flexion during the test, and the investigator uses their other hand to stabilize the shoulder to prevent elevation (shrugging) of the scapula. A positive Hawkins-Kennedy test was recorded if the participant reported pain at the anterior or lateral shoulder during the maneuver. Park et al. (34) reported that this test has a positive likelihood ratio of 2.12 and an overall accuracy of 70%.

According to the literature, the utility of the Hawkins-Kennedy test and painful arc tests increases when the results are clustered (analyzed together as 1 test). Park et al. (34) reported a positive likelihood ratio of 5.05 when both tests are positive and found these 2 tests to offer the greatest diagnostic utility for SIS. As a result, final analysis was performed using the SIS testing cluster (both tests must be positive to indicate a positive SIS testing cluster) as opposed to individual test results.

Statistical Analyses

Collected data were transferred to SPSS (version 15.0 for Windows; SPSS, Inc., Chicago, IL, USA) statistical program for analysis. Means, *SDs*, and ranges of descriptive data from the WT and control groups were generated for comparison using an independent *t*-test for ratio data (age, height, and body mass) and the Mann-Whitney *U*-test for ordinal data (body mass index). Inferential statistical analysis for the dependent variables was performed with the appropriate nonparametric tests. Specifically, the painful arc sign and Hawkins-Kennedy tests were clustered (a positive test on both was considered positive for testing cluster) and analyzed as nominal data using a Pearson's χ^2 or Fisher's exact test (when there was a count of <5 for a cell) to determine

whether a significant difference in the frequency of test results was present between the WT and control group. Additionally, a Pearson's χ^2 or Fisher's exact test (when there was a count of <5 for a cell) was used to determine if a significant difference existed between those WT participants with a positive SIS testing cluster and the performance of specific exercises deemed to be high risk from previous case reports. A phi coefficient (Φ) was used to interpret the strength of the association. Finally, a Pearson's χ^2 test was used to determine whether a significant difference existed between those WT participants with a positive SIS testing cluster and reported shoulder pain within the past 72 hours. A phi coefficient (Φ) was used to interpret the strength of the association. The phi coefficient (Φ) values were interpreted using the guidelines offered by Healy (19) for nominal associations, whereas 0.0–0.10 is weak, 0.11–0.29 is moderate, and values ≥ 0.30 are considered to have a strong association.

An a priori power analysis using the G-Power statistical software version 3.03 (9) determined that a total sample size of $n = 88$ would be required for 80% power if a medium effect size was posited. The alpha level was set at 0.05, and the p value was considered significant if ≤ 0.05 (2-tailed test) for all hypotheses.

RESULTS

Painful Arc Sign and Hawkins-Kennedy Test

A significant difference existed between groups for the presence of a positive painful arc sign ($p = 0.01$). Twenty-two percent of shoulders tested in the WT group had a positive painful arc sign compared with 6% of controls. A significant difference also existed between the groups for the presence of a positive Hawkins-Kennedy test ($p < 0.001$) as well. Fifty-two percent of the WT participants had a positive Hawkins-Kennedy test compared with 19% of controls.

When a positive painful arc sign and Hawkins-Kennedy test were clustered, 20% of shoulders from the WT group tested positive compared with 4.8% of controls. This difference was significant, $p < 0.001$. Table 2 highlights

findings from the testing results for each group. Finally, of the 9 WT participants (18 shoulders) who reported having their program designed by a professional who is certified or licensed to prescribe exercise programs or being certified or licensed themselves only 6% of the shoulders tested (1 participant) had a positive SIS testing cluster.

Program Design Characteristics

Based on questionnaire responses from the WT group, 59% of participants performed lateral deltoid raises to a height of greater than 90° and 67% performed upright rows in a manner that elevated elbows above 90° both of which may alter normal shoulder biomechanics and create impingement during the exercise. Exercise selection characteristics for the participants in this investigation indicated that there was a significant difference ($p \leq 0.004$) for the presence of a positive SIS testing cluster among individuals who performed either lateral deltoid raises or upright rows to a height above 90° and those who did not (Table 3). Moreover, the presence of positive findings from the SIS testing cluster among individuals who performed external rotator strengthening was significantly less than those who did not ($p < 0.001$). No significant differences ($p \geq 0.06$) were identified between individuals with a positive vs. negative SIS testing cluster and performance of flat bench, incline bench, chest flies, dips, behind-the-neck military press, and behind-the-neck latissimus dorsi pull-downs.

In regard to exercise selection, a significant ($p = 0.002$) strong association was found between the lateral deltoid raise (when performed to an angle $>90^\circ$) exercise and the SIS testing cluster, ($\Phi = 0.32$). A significant ($p = 0.004$) strong association was also found between the upright row (when performed to an angle $>90^\circ$) and a positive SIS testing cluster ($\Phi = 0.30$). A significant ($p < 0.001$) strong inverse relationship ($\Phi = -0.38$) was identified between performance of external rotator strengthening and a positive SIS testing cluster.

Pain Reports

In regard to pain, 26% of WT participants reported having shoulder pain during WT in the past 72 hours. Significant

TABLE 2. Group characteristics for results of the Hawkins-Kennedy and painful arc tests.

Group	Hawkins-Kennedy, % positive	p^*	Painful arc, % positive	p^\dagger	Cluster, % positive	p^\ddagger
WT [‡]	52	<0.001 §	22	0.01§	20	<0.001 §
Control	19		6		5	

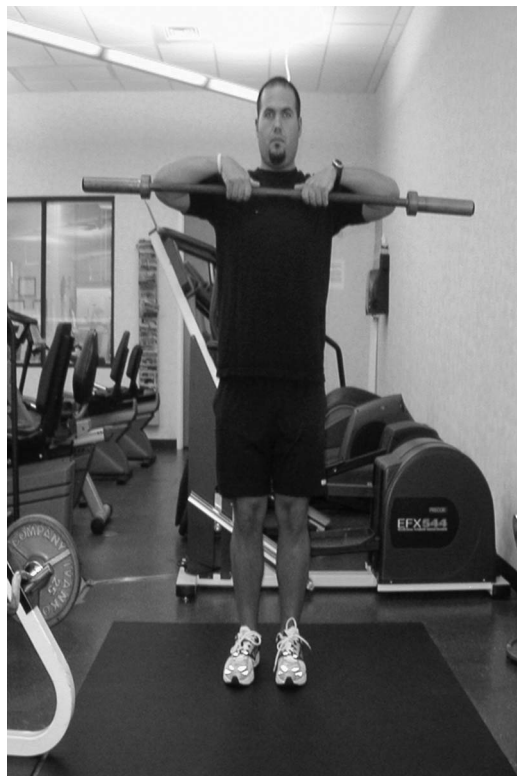
* χ^2 test.
 †Fisher's exact test.
 ‡WT = weight training.
 §Statistically significant.

TABLE 3. Testing cluster results based on exercise selection.

Exercise selection	Cluster, % positive	p
Performed upright rows $>90^\circ$	18	0.004*†
Performed lateral deltoid raises $>90^\circ$	20	0.002*†
External rotator strengthening	2	<0.001 ‡§

* χ^2 test.
 †Statistically significant from those that performed similar exercise $<90^\circ$.
 ‡Fisher's exact test.
 §Performance resulted in significantly less positive testing cluster results than those who did not perform.

differences ($p = 0.034$) were present when comparing results of the SIS testing cluster among individuals with and without reported shoulder pain in the past 72 hours. Moreover, a significant ($p = 0.034$) relationship was identified between

**Figure 4.** Modification to upright row.**Figure 5.** Side-lying external rotator strengthening.

reports of shoulder pain in the past 72 hours and the SIS testing cluster ($\Phi = 0.22$).

DISCUSSION

Although WT is considered a heterogeneous activity, we recruited men who participated primarily for recreational purposes so that inferences may be made from the results. From a descriptive perspective, findings from this investigation are consistent with a previous case series investigation suggesting that individuals who participate in WT may be predisposed to SIS (25). It should be noted that the aforementioned case series lacked a control group (25), thus we are limited in our ability to directly compare our results. Despite limited research for comparison, this investigation adds to the body of knowledge and provides a platform for further investigations.

Although the type of WT one performs may be heterogeneous, none of the participants in this investigation were reported to be competitively training for events such as bodybuilding or powerlifting or have known preexisting injuries or previous surgery. An important variable to consider when evaluating the results of this investigation is that individuals were recruited based on WT participation as opposed to those seeking care. Although 26% of WT participants did have shoulder pain during training in the past 72 hours, one cannot surmise that these participants are similar to those seeking care from a pain perspective. Although speculative, one might surmise that those seeking care would have a higher prevalence of positive SIS testing. Moreover, we recruited only men, thus the results cannot be generalized to women.

A multitude of clinical examination tests have been described in the literature for identifying SIS. This investigation used 2 of the more common tests that have published diagnostic utility values so that the merits and limitations of our results could be reasonably interpreted. Additionally, we

chose 2 tests that when clustered have been reported to have the greatest diagnostic utility for identifying SIS (34). It should be recognized, however, that other tests exist and that the addition of a qualitative assessment of rotator cuff weakness may have improved our predictive ability to identify characteristics of SIS (34). Moreover, we did not evaluate movement quality of the shoulder complex, which would have provided further understanding of the nature of SIS among the participants.

Because our participants were not seeking care for shoulder pain, we did not expect to identify such a high prevalence of positive testing for SIS. The painful arc sign and Hawkins-Kennedy test have both been validated as clinical tests for SIS with accuracy of 76 and 70, respectively (34). Pooled results from meta-analysis suggest that the Hawkins-Kennedy possesses high sensitivity (80%), whereas the painful arc sign possesses high specificity (76%) (20). Retrospectively looking at our results, it is apparent that a substantial number of WT participants had positive Hawkins-Kennedy test results to a greater degree than the painful arc sign, which would not be unexpected given the aforementioned statistical properties of each test. Specifically, the Hawkins-Kennedy test has lower specificity, 56%, which suggest the presence of false positive results to a greater degree than the painful arc sign. We used the testing cluster as a means of mitigating the potential for false positive interpretation of results. On the contrary, the painful arc sign has a sensitivity of 53%, which suggests that there may be a higher presence of false negative findings, which is not unexpected given the differences between the 2 tests. Although this is a reasonable consideration, the prevalence of positive test results identified in this investigation may perhaps minimize this concern.

Given the aforementioned validity reports and the higher than anticipated prevalence of clinical characteristics of SIS among the WT participants, one might speculate that the results are inclusive of false positive findings. However, we chose to analyze these tests using a testing cluster, which would theoretically reduce false positive results. When both tests are combined, the diagnostic utility improves with pretest to posttest odds from 1.86 to 9.36 (34).

When assessing the association between exercise selection reported on the questionnaire and clinical characteristics of SIS, 3 exercises (external rotator strengthening, lateral deltoid raises greater than 90°, and upright rows with elbows elevated above shoulder height [90°]) had significant associations ($p \leq 0.004$). The results of the lateral deltoid raises and upright rows were reasonably predictable for WT participants who performed exercises in an “above shoulder height” position based on biomechanical principles and the results of investigations where maximum impingement was reported to occur at 90° when the arm was internally rotated (15,16,28). Specifically, elevation of the humerus above shoulder height combined with internal rotation has been found to cause impingement of the rotator cuff between the

bony humeral head and acromion process, thus compulsory assumption of this position while the joint is loaded during WT may lead to SIS and ultimately rotator cuff pathology. Interestingly, the association between having a positive SIS testing cluster was stronger among participants performing both lateral deltoid raises and upright rows above shoulder height in comparison to either of the exercises independently. One reason may lie in the cumulative effect of both exercises. On the contrary, performance of external rotation strengthening had a significant inverse association with clinical characteristics associated with SIS, which may suggest a protective effect. One plausible explanation for this is that the external rotators serve to stabilize the glenohumeral joint. Contraction of the rotator cuff muscles may cause the humerus to translate in a direction consistent with the angle of contraction (26), thus the external rotators may provide restraint to superior migration of the humeral head during abduction, consequently decreasing the propensity for SIS. Interestingly, few participants performed both external rotator strengthening and either lateral deltoid raises or upright rows greater than 90°. Of those participants who performed external rotator strengthening, only 2% of shoulders tested positive for the SIS cluster compared with 20% of shoulders for participants who performed lateral deltoid raises (above 90° shoulder height) and 18% of shoulders among those performing upright rows above shoulder height. One might postulate that individuals whose programs are inclusive of external rotator strengthening may intentionally avoid at risk exercises.

An important consideration when interpreting the results of this investigation is the level of supervision and instruction the participants may have received to develop their exercise routine. In regard to supervision, none of the participants reported being supervised in any manner during their routine. This was not an unexpected finding given that the average reported years of WT participation was 9 years. Of the 9 WT participants who reported having their program designed by a professional who is certified or licensed to prescribe exercise programs or being certified or licensed themselves, only 1 had a positive SIS testing cluster. Thus, of the total shoulders found to have a positive SIS testing cluster, 95% had no supervision or formal training. This suggests that individuals participating in WT are less likely to have signs of SIS if their program is designed by a professional who is certified or licensed to prescribe exercise programs; however, generalization of these finding is difficult given a the relatively small group size of 9.

Although the precise etiology of the SIS findings among the WT participants in this study may be uncertain, evidence is available from this investigation and previous research to suggest that exercises requiring the arm to elevate above 90° with internal rotation may be a predisposing factor (15,16). It is important to recognize that the individuals in this study were not seeking care for shoulder pain, thus the presence of clinical characteristics of SIS may be considered pathologically occult.

It should be recognized that the results of this investigation are specific to young adult men who recreationally participate in WT, thus cannot be generalized to individuals of age <18 years, women, or individuals training for competition. Future studies using the aforementioned cohorts are needed before one can generalize the finding of this investigation. Long-term prospective investigations are needed to determine a causative effect of SIS in the WT population.

PRACTICAL APPLICATIONS

The professions involved in both the prescription of exercise and the evaluation and treatment of musculoskeletal disorders must develop WT guidelines that optimize safety, reduce injury risk, and prevent musculoskeletal dysfunction. Injury risk may be mitigated through proper supervision and evidence-based changes in exercise prescription and technique.

The ability of clinicians and strength and conditioning professionals to recognize “at risk” training patterns requires an awareness of documented injury trends and risk factors. Addressing the modifiable risk factors identified in this investigation, such as abduction of the humerus above 90° with internal rotation and limiting upward ascent to below 90° (shoulder height) (Figure 4) during select upper extremity exercises, may serve to prevent and/or minimize symptoms resulting from SIS.

The information gleaned from this investigation provides WT participants and strength and conditioning professionals with evidence-based exercise guidelines. Avoiding performance of lateral deltoid raises and upright rows beyond an angle of 90° and efforts to strengthen the external rotators (Figure 5) may serve as a useful means to mitigate characteristics associated with SIS.

ACKNOWLEDGMENTS

This study was supported through funding from the Nova Southeastern, University, Health Professions Division, Faculty Development Research Grant.

REFERENCES

- American College of Sports Medicine. Position stand on the recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness in healthy adults. *Med Sci Sports Exerc* 22: 265–274, 1990.
- American Physical Therapy Association. *Guide to Physical Therapist Practice*. Alexandria, Virginia: American Physical Therapy Association, 1999.
- Barlow, JC, Benjamin, BW, Birt, P, and Hughes, CJ. Shoulder strength and range-of-motion characteristics in bodybuilders. *J Strength Cond Res* 16: 367–372, 2002.
- Budoff, JE and Gordon, L. Surgical repair of a traumatic latissimus dorsi avulsion: A case report. *Am J Orthop (Belle Mead NJ)* 29: 638–639, 2000.
- Cadogan, A, Laslett, M, Hing, W, McNair, P, and Williams, M. Interexaminer reliability of orthopaedic special tests used in the assessment of shoulder pain. *Man Ther* 16: 131–135, 2011.
- Centers for Disease Control and Prevention (CDC). Trends in strength training—United States, 1998–2004. *MMWR Morb Mortal Wkly Rep* 55: 769–772, 2006.
- Cope, MR, Ali, A, and Bayliss, NC. Biceps rupture in body builders: Three case reports of rupture of the long head of the biceps at the tendon-labrum junction. *J Shoulder Elbow Surg* 13: 580–582, 2004.
- Durall, CJ, Manske, RC, and Davies, GJ. Avoiding shoulder injury from resistance training. *Strength Cond J* 23: 10–18, 2001.
- Faul, F, Erdfelder, E, Buchner, A, and Lang, AG. Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behav Res Methods* 41: 1149–1160, 2009.
- Fees, M, Decker, T, Snyder-Mackler, L, and Axe, MJ. Upper extremity weight-training modifications for the injured athlete. A clinical perspective. *Am J Sports Med* 26: 732–742, 1998.
- Feigenbaum, MS and Pollock, ML. Prescription of resistance training for health and disease. *Med Sci Sports Exerc* 31: 38–45, 1999.
- Fleck, SJ and Falkel, JE. Value of resistance training for the reduction of sports injuries. *Sports Med* 3: 61–68, 1986.
- Gill, IP and Mbubaegbu, C. Fracture shaft of clavicle, an indirect injury from bench pressing. *Br J Sports Med* 38: E26, 2004.
- Goertzen, M, Schoppe, K, Lange, G, and Schulitz, KP. Injuries and damage caused by excess stress in bodybuilding and power lifting [in German]. *Sportverletz Sportschaden* 3: 32–36, 1989.
- Graichen, H, Bonel, H, Stammberger, T, Englmeier, KH, Reiser, M, and Eckstein, F. Subacromial space width changes during abduction and rotation—a 3-D MR imaging study. *Surg Radiol Anat* 21: 59–64, 1999.
- Graichen, H, Bonel, H, Stammberger, T, Heuck, A, Englmeier, KH, Reiser, M, and Eckstein, F. A technique for determining the spatial relationship between the rotator cuff and the subacromial space in arm abduction using MRI and 3D image processing. *Magn Reson Med* 40: 640–643, 1998.
- Gross, ML, Brenner, SL, Esformes, I, and Sonzogni, JJ. Anterior shoulder instability in weight lifters. *Am J Sports Med* 21: 599–603, 1993.
- Haupt, HA. Upper extremity injuries associated with strength training. *Clin Sports Med* 20: 481–490, 2001.
- Healy, JF. *The Essentials of Statistics: A Tool for Social Research*. Belmont, CA: Wadsworth, 2010.
- Hegedus, EJ. Which physical examination tests provide clinicians with the most value when examining the shoulder? Update of a systematic review with meta analysis of individual tests. *Br J Sports Med* 46: 964–978, 2012.
- Heggland, EJ and Parker, RD. Simultaneous bilateral glenoid fractures associated with glenohumeral subluxation/dislocation in a weightlifter. *Orthopedics* 20: 1180–1183, 1997.
- Jia, X, Ji, JH, Pannirselvam, V, Petersen, SA, and McFarland, EG. Does a positive neer impingement sign reflect rotator cuff contact with the acromion? *Clin Orthop Relat Res* 469: 1590–1593, 2011.
- Jones, C, Christensen, C, and Young, M. Weight training injury trends. *Phys Sportsmed* 28: 1–7, 2000.
- Keogh, J, Hume, PA, and Pearson, S. Retrospective injury epidemiology of one hundred one competitive Oceania power lifters: The effects of age, body mass, competitive standard, and gender. *J Strength Cond Res* 20: 672–681, 2006.
- Kolber, MJ, Corrao, M, and Hanney, WJ. The relationship between exercise selection and reported shoulder pain during weight-training. Presented as a poster at National Strength and Conditioning Association, National Conference. Orlando, Florida, July 2010.
- Kolber, MJ, Corrao, M, and Hanney, WJ. Clinical characteristics of shoulder impingement: A pilot investigation of healthy weight-training participants. Presented as a poster at National Strength and Conditioning Association, National Conference, Rhode Island, July 2012.

27. Konig, M and Biener, K. Sport-specific injuries in weight lifting [in German]. *Schweiz Z Sportmed* 38: 25–30, 1990.
28. Levangie, PK and Norkin, CC. *Joint Structure & Function: A Comprehensive Analysis*. Philadelphia, PA: F.A. Davis, 2005.
29. Litaker, D, Piro, M, Bilbeisi, EH, and Brems, J. Returning to the bedside: Using the history and physical examination to identify rotator cuff tears. *J Am Geriatr Soc* 48: 1633–1637, 2000.
30. Mazur, LJ, Yetman, RJ, and Risser, WL. Weight-training injuries. Common injuries and preventative methods. *Sports Med* 16: 57–63, 1993.
31. Michener, LA, Walsworth, MK, Doukas, WC, and Murphy, KP. Reliability and diagnostic accuracy of 5 physical examination tests and combination of tests for subacromial impingement. *Arch Phys Med Rehabil* 90: 1898–1903, 2009.
32. Neviasser, TJ. Weight lifting. Risks and injuries to the shoulder. *Clin Sports Med* 10: 615–621, 1991.
33. Nomden, JG, Slagers, AJ, Bergman, GJD, Winters, JC, Kropmans, TJB, and Dijkstra, PU. Interobserver reliability of physical examination of shoulder girdle. *Man Ther* 14: 152–159, 2009.
34. Park, HB, Yokoyta, A, Harpreet, SG, El Rassi, G, and McFarland, EG. Diagnostic accuracy of clinical tests for the different degrees of subacromial impingement syndrome. *J Bone Joint Surg Am* 87: 1446–1455, 2005.
35. Reeves, RV, Laskowski, ER, and Smith, J. Weight training injuries: part 1: Diagnosing and managing acute conditions. *Phys Sportsmed* 26: 67, 1998.
36. Reeves, RV, Laskowski, ER, and Smith, J. Weight training injuries: part 2: Diagnosing and managing chronic conditions. *Phys Sportsmed* 26: 54, 1998.
37. Schoenfeld, B, Kolber, MJ, and Haimes, JE. The upright row: Implications for preventing subacromial impingement. *Strength Cond J* 33: 25–28, 2011.
38. Starkey, DB, Pollock, ML, Ishida, Y, Welsch, MA, Brechue, WF, Graves, JE, and Feigenbaum, MS. Effect of resistance training volume on strength and muscle thickness. *Med Sci Sports Exerc* 28: 1311–1320, 1996.