Evaluation of Shoulder Strength and Kinematics as Risk Factors for Shoulder Injury in United States Special Forces Personnel

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Background: Musculoskeletal injuries at the shoulder are highly prevalent and place a large burden on United States Special Forces personnel. Literature is lacking regarding the risk factors for these types of injuries.

Purpose/Hypothesis: The purpose of this study was to evaluate the association of shoulder strength and kinematic characteristics, which have shown retrospective associations with shoulder conditions/injuries, with prospectively collected shoulder injuries. We hypothesized that lower strength and abnormal kinematics would be predictive of future shoulder injury.

Study Design: Case-control study; Level of evidence, 3.

Methods: A total of 140 male Special Forces operators underwent a musculoskeletal evaluation of the shoulder that included a scapular kinematic assessment during a humeral elevation task and isokinetic strength testing of the scapular protractors/retractors, external/internal rotators, and elevators of the shoulder. From strength assessments, ipsilateral strength ratios and bilateral strength asymmetries were also calculated. Musculoskeletal injuries of the shoulder were collected prospectively by use of medical chart reviews at 365 days following the evaluation. Separate generalized estimating equations (GEEs) and simple logistic regressions were used to analyze the association between baseline predictors and development of shoulder injury.

Results: Results of the GEEs showed no significant prediction of shoulder injury by shoulder strength (odds ratio [OR], 1.00-1.03), ipsilateral strength ratios (OR, 0.43-2.12), or scapular kinematics (OR, 0.99-1.01). Logistic regression indicated that none of the bilateral asymmetries were significantly predictive of shoulder injury (OR, 1.00-1.04).

Conclusion: The results indicate that shoulder strength and kinematic characteristics are not risk factors for shoulder injury in the Special Forces population. These findings are in opposition to the general findings of previous research using a retrospective analysis.

Keywords: prospective; upper extremity; military; biomechanics; isokinetic

Military personnel under the United States Special Operations Command are commonly known as the Special Operations Forces (SOF). Within the SOF, musculoskeletal injuries (MSIs) occur at a high rate (24.5-38.4 injuries per 100 patient-years) and place a significant burden on health care utilization, operational readiness, and the longevity of personnel.[1,13,17,21,23] Furthermore, recent evidence has shown that a large percentage of these injuries are preventable (76.9%).[1]

Previous research has identified the shoulder as one of the most commonly injured anatomic locations for SOF personnel.[1,13,17,23] In Naval Special Warfare Operators, shoulder injuries were the first or second most common injury, accounting for 19% to 24% of all MSIs.[13,23] Likewise, in Army Special Forces groups, the shoulder was shown to be the first or second most commonly injured location, accounting for 10% to 23.1% of all injuries.[1,17] Despite the high incidence of shoulder injuries among these SOF groups, little is known about risk factors specific to this injury and population.

Several risk factors in nonmilitary populations have been investigated previously, with a number of studies focusing on the role of the scapular kinematics and activation of the scapular musculature.[5-8,12,15,16,26,27] A review by Struyf et al[27] reported that individuals with shoulder impingement and instability demonstrated decreased

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upward rotation and increased internal rotation compared with healthy participants during humeral elevation.[27] Patients with a shoulder impingement have also shown a decreased posterior tilt in addition to the decreased upward rotation and decreased external rotation during humeral elevation.[15,16,27] Other studies have reported decreased peak torques of the protractor muscles and lower ipsilateral protraction to retraction ratios or a decreased activation of the serratus anterior muscle and increased activation of the upper trapezius in patients with shoulder injuries.[5-8,12,15] However, the majority of these studies were retrospective in nature, and therefore it cannot be established whether the observed alterations to scapular kinematics were a precipitant for or result of shoulder injuries.

Another risk factor that has been widely evaluated in nonmilitary populations is the role of strength of the shoulder musculature.[2,3,9,18-20,28,29] Several studies have reported that decreased strength of the internal/external rotators and abnormal (high or low) strength ratios for ipsilateral muscle groups are associated with shoulder injuries.[2,3,9,18,19,28,29] However, again, much of this work was retrospective in nature and was conducted in nonmilitary populations. In addition to absolute strength and strength ratios, bilateral strength asymmetries may present a potential risk factor with prognostic value. Sapega[24] initially described 3 categories for side-to-side differences (bilateral strength discrepancies) in muscle groups: <10% difference (normal), 10%-20% difference (possibly abnormal), and >20% difference (probably abnormal). Several studies have reported associations between bilateral strength discrepancies greater than 10% to 15% and injury risk in the lower extremity (LE).[22,31] However, no previous work has investigated whether strength asymmetries of the upper extremity (UE) musculature are predictive of injury to the UEs.

Prospective studies conducted in SOF personnel identifying modifiable risk factors for MSIs to the shoulder are lacking. Special Tactics (ST) operators are a subgroup of the Special Forces, operating under Air Force Special Operations Command (AFSOC). Some of the unique demands of ST operators include airfield reconnaissance, assessment, and control, as well as aircraft and personnel recovery. Previous work in our laboratory (unpublished data, 2018) has shown that ST operators demonstrate a high rate of MSI and that a large portion of these injuries are to the shoulder region, making these personnel an ideal group for risk factor identification.

Subsequently, the purpose of this study was to determine whether strength of the shoulder musculature and kinematic characteristics of shoulder movement are predictive of shoulder injuries in ST operators. Many of these variables have been proposed as risk factors for shoulder injury based on retrospectively identified associations. Further, both strength and kinematic characteristics are modifiable through training and therapy, making them viable targets for intervention, if shown to be related to the development of shoulder MSIs. Therefore, we sought to reexamine their validity as prospective risk factors for the development of shoulder pathologies.

METHODS

Participants

Data for this study were obtained from a large prospective-cohort study that was conducted in ST operators at Hurlburt Field Air Force Base (Florida, USA) and included a total of 140 participants. Participants at the base were recruited via flyers and informational sessions with unit commanders. All interested participants who contacted the study team were then given more detailed information on the study and testing and were ultimately scheduled for a laboratory visit. For the current study, injury data and at least partial laboratory testing data were available for a total of 121 participants (mean ± SD: age, 27.6 ± 5.2 years; height, 177.4 ± 5.8 cm, weight, 83.8 ± 8.3 kg). Further, access to the ST operators and time restrictions limited the number of participants who were available to complete the scapular kinematic testing to 71. Therefore, the total sample sizes for analyses using strength and kinematic variables were 121 and 71, respectively.

All participants were medically cleared for unrestricted duty and were free of traumatic brain injuries, MSIs in the 3 months before evaluation, and pulmonary, cardiovascular, metabolic, neurological and vestibular disorders. The experimental design was a cohort study, using a prospective, longitudinal follow-up. Participants underwent a musculoskeletal evaluation of the shoulder that included a scapular kinematic assessment and isokinetic strength testing. MSIs of the shoulder were prospectively monitored by use of medical chart review 365 days after the musculoskeletal evaluation. Before testing, participants were fully informed of the testing procedures and provided written informed consent. This study was approved by the institutional review board at the local university.

Procedures

Kinematic characteristics of the shoulder, focusing on scapular positioning during humeral elevation, were obtained

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Ethical approval for this study was obtained from the University of Pittsburgh Institutional Review Board.

Figure 1. Depiction of testing procedures for humeral elevation task and calculation of shoulder kinematics.

using a 3-dimensional (3D) motion capture system (Vicon) consisting of 10 infrared cameras. Retroreflective markers were placed bilaterally at the acromioclavicular joint, acromion (3-marker cluster), acromial angle, medial border of the scapula, inferior angle of the scapula, lateral and medial epicondyles of the humerus, styloid processes of the ulna and radius, and caput of the second metacarpal (Figure 1). Markers were also placed at the C7 and T10 spinous processes, jugular notch, and xiphoid process (Figure 1). A static capture was then collected with the participant standing upright, feet facing forward, and arms in an anatomically neutral position. Participants performed 5 continuous repetitions of humeral elevation in the scapular plane while holding a 2-lb weight in each arm with their elbows in extension. A metronome was used to control the velocity of movements (30 bpm), and 2 custom-made poles were used to control the range of motion. All 3D coordinate data were collected at a sampling rate of 250 Hz.

Isokinetic strength for shoulder elevation, protraction/retraction, and internal/external rotation was measured with an isokinetic dynamometer (Biodex System 4; Biodex Medical Systems). Participants were restrained and positioned according to the manufacturer's guidelines. Participants performed 6 warm-up trials: 3 at submaximal effort and 3 at maximal effort. After a 2-minute rest period, participants were asked to perform 5 concentric/concentric repetitions at 60 deg/s. Average peak torque was calculated as the average of 5 repetitions and was normalized to body weight for data analysis (N·m/kg). The Biodex isokinetic dynamometer has shown good reliability (intraclass correlation coefficient = 0.97-0.99) and precision in measurements of shoulder strength.[11]

Injury tracking was performed as described previously.[14] Injuries were recorded by the medical staff operating at Hurlburt Field Air Force Base, who had no role in, or knowledge of, laboratory testing. Prospective injuries were collected from the participants' medical charts over a 365-day period from the date of testing, by a member of the research team with a clinical, sports medicine background (ie, an athletic trainer or physical therapist). All research team members received training on reviewing the medical charts of study participants. MSI was operationally defined as an injury of the musculoskeletal system that resulted in medical attention being sought. Shoulder injuries were defined as any injury that occurred to the shoulder complex (ie, glenohumeral joint, sternoclavicular joint, acromioclavicular joint, and scapulothoracic joint) as well as any injury of the muscles that crossed the shoulder. These included both chronic and acute injuries. Some examples of injuries that were included for analysis were sprains, strains, and fractures, whereas lacerations and contusions were examples of injuries that were excluded. Finally, any shoulder injury was the variable of interest, so while recurrent injuries were recorded, patients were counted only once in the injured group.

Data Reduction

Upper extremity kinematic findings during the humeral elevation task were first processed by use of Nexus software (v 1.8.5; Vicon) and using a standard plug-in gait–full body model, a modified version of the Newington–Helen Hayes gait model. Raw kinematics were filtered by use of a Woltring filter routine.[30] The static capture was used for anatomic reference, and Euler rotation angles were calculated from 3D coordinate data. Finally, a custom-written Matlab code (v R2014a; MathWorks) was used to identify all kinematic variables, including scapular protraction/retraction, downward/upward rotation, and anterior/posterior tilt. All variables were identified at 90° and 120° of humeral elevation and calculated as the average of 5 repetitions.

Bilateral strength asymmetries were calculated by the following formula, where *NDL* indicates the average peak torque for the nondominant limb and *DL* indicates the same for the dominant limb:

$$Asymmetry = \left| \left(\frac{NDL}{DL} \right) - 1 \right|.$$

Ipsilateral protraction/retraction and external/internal ratios were simply calculated by dividing the average peak torque of the protractor or external rotators by that of the retractor or internal rotators, respectively. For reference, values of zero would indicate no difference for bilateral strength asymmetries, and values of 1.0 would indicate no difference for ipsilateral strength ratios.

Statistical Analyses

All statistical tests were performed with SPSS Statistics 23 (IBM Corp) and STATA 15.1 (StataCorp LP). Descriptive statistics were calculated for all variables. Separate generalized estimating equations (GEEs) were formulated to assess the univariate prediction of any shoulder injury (outcome) by isokinetic shoulder strength measures, ipsilateral

TABLE 1
Descriptive Statistics for all Predictor Variables[a]

	Uninjured		Injured	
	Mean ± SD	95% CI	Mean ± SD	95% CI
Shoulder (uninjured, n = 99; injured, n = 22)				
External rotation strength	46.31 ± 9.26	44.61 to 48.01	47.76 ± 9.77	43.96 to 51.56
Internal rotation strength	69.14 ± 18.70	65.74 to 72.54	73.02 ± 19.93	65.32 to 80.72
Protraction strength	527.23 ± 123.42	504.23 to 550.23	544.49 ± 111.27	501.49 to 587.49
Retraction strength	529.71 ± 119.02	507.71 to 551.71	564.59 ± 110.08	522.59 to 606.59
Elevation strength	541.48 ± 97.52	523.48 to 559.48	575.81 ± 87.35	541.81 to 609.81
External/internal rotation SR	0.70 ± 0.17	0.67 to 0.73	0.65 ± 0.10	0.61 to 0.69
Protraction/retraction SR	1.01 ± 0.21	0.97 to 1.05	1.04 ± 0.27	0.92 to 1.16
Bilateral external rotation SA	9.11 ± 6.49	7.82 to 10.4	9.76 ± 5.58	7.29 to 12.23
Bilateral internal rotation SA	10.52 ± 9.19	8.69 to 12.36	10.43 ± 7.41	7.14 to 13.71
Bilateral protraction SA	10.95 ± 8.35	9.25 to 12.65	11.40 ± 9.73	7.08 to 15.71
Bilateral retraction SA	14.81 ± 13.49	12.06 to 17.56	13.74 ± 10.70	8.00 to 18.48
Bilateral elevation SA	9.54 ± 6.14	8.29 to 10.78	11.00 ± 6.42	8.15 to 13.32
Scapula (uninjured, n = 54; injured, n = 17)				
Protraction/retraction at 90°	35.47 ± 9.33	33.78 to 37.17	34.48 ± 6.80	31.88 to 37.08
Downward/upward rotation at 90°	27.29 ± 6.29	26.09 to 28.49	27.74 ± 8.21	24.54 to 30.94
Anterior/posterior tilt at 90°	–7.90 ± 7.30	–9.20 to –6.60	–8.45 ± 5.72	–10.65 to –6.25
Protraction/retraction at 120°	39.18 ± 10.90	37.18 to 41.18	39.94 ± 7.32	37.14 to 42.74
Downward/upward rotation at 120°	35.18 ± 6.86	33.88 to 36.48	34.64 ± 6.95	31.94 to 37.34
Anterior/posterior tilt at 120°	–4.41 ± 9.13	–6.11 to –2.71	–5.61 ± 5.87	–7.91 to –3.31

[a]All strength variables are given in N·m/kg all bilateral asymmetry variables are expressed as percentages; all scapular kinematic variables are given in degrees of rotation. SA, strength asymmetry; SR, strength ratio.

strength ratios, and scapular kinematics during humeral elevation. The GEEs were developed by use of a logit link, which accounted for the fact that both extremities belonged to the same person. Simple logistic regression equations were used to assess the univariate prediction of shoulder injury by bilateral strength asymmetries. For this analysis, a participant-wise analysis was conducted, with injury to any shoulder as the outcome.

RESULTS

During the 365-day follow-up period, 26 of the 140 ST operators who participated in some form of the full prospective study (thus, 18.6% of the sample) experienced an unintentional shoulder injury. Of the 26 injured operators, 5 sustained a second shoulder injury, all on the contralateral side of the first injury. For the subset of participants included in the current analyses, 22 of 121 participants experienced a shoulder injury. A complete description of the incidence of MSI, causes, and associated costs across the sample is described elsewhere.[14] In short, injury types included shoulder impingement (27.0%), pain/spasm/ache (19.2%), muscle strain/tear (15.4%), tendinitis (15.4%), labral tear (11.6%), dislocation/subluxation (3.8%), ligament sprain (3.8%), and nerve damage (3.8%). The majority of injuries with a known cause were the result of weightlifting activities (38.5%), with 30.8% of injuries having an unspecified cause. The remaining causes included training activities (11.5%), recreational activity/sport (11.5%), and occupational duties during deployment (7.7%).

TABLE 2
Results of Generalized Estimation Equations for the Univariate Prediction of Shoulder Injury by Shoulder Strength, Strength Ratios, and Scapular Kinematics[a]

	Odds Ratio (95% CI)	*P*
Shoulder		
External rotation strength	1.016 (0.973-1.016)	.473
Internal rotation strength	1.010 (0.990-1.032)	.328
Shoulder protraction strength	1.001 (0.998-1.004)	.514
Shoulder retraction strength	1.003 (0.999-1.006)	.138
Shoulder elevation strength	1.033 (0.999-1.008)	.071
External/internal rotation SR	0.433 (0.147-1.276)	.177
Protraction/retraction SR	2.123 (0.272-16.667)	.473
Scapula		
Protraction/retraction at 90°	0.988 (0.952-1.025)	.523
Downward/upward rotation at 90°	1.014 (0.932-1.103)	.755
Anterior/posterior tilt at 90°	0.991 (0.935-1.051)	.766
Protraction/retraction at 120°	1.007 (0.977-1.038)	.672
Downward/upward rotation at 120°	0.991 (0.992-1.066)	.806
Anterior/posterior tilt at 120°	0.986 (0.947-1.027)	.498

[a]SR, strength ratio.

Descriptive statistics for all predictor variables, by injury grouping, are reported in Table 1. Results of the GEE models for the prediction of shoulder injuries by shoulder muscle strength, ipsilateral strength ratios, and scapular kinematics are summarized in Table 2. Odds ratios (ORs) for shoulder muscle strength variables ranged from 1.001 to 1.033 (an OR of >1 indicates higher values associated with higher risk for injury), with no variables showing

TABLE 3
Results of Simple Logistic Regression Equations for the Univariate Prediction of Shoulder Injury by Bilateral Strength Asymmetries[a]

	Odds Ratio (95% CI)	*P* Value
Bilateral external rotation SA	1.014 (0.944-1.089)	.706
Bilateral internal rotation SA	0.999 (0.948-1.053)	.963
Bilateral protraction SA	1.006 (0.954-1.061)	.825
Bilateral retraction SA	0.993 (0.956-1.032)	.726
Bilateral elevation SA	1.037 (0.965-1.115)	.319

[a]SA, strength asymmetry.

significant prediction of shoulder injuries (P = .071-.514). For ipsilateral strength ratios, neither external/internal rotation (OR, 0.433; P = .177) nor protraction/retraction (OR, 2.123; P = .473) showed significant prediction of shoulder injuries. Finally, ORs for scapular kinematics ranged from 0.986 to 1.014, with no variables significantly predictive of shoulder injuries (P = .498-.806). Results of simple logistic regression equations for the prediction of shoulder injuries by bilateral strength asymmetries are presented in Table 3 and mirrored the results for strength, strength ratios, and scapular kinematics (OR, 0.993-1.037; P = .319-.963).

DISCUSSION

The prevention of MSIs has been identified as a priority in SOF populations, given the high prevalence and impact of these injuries.[1,13,17,23] A number of studies have identified the shoulder as one of the most commonly injured anatomic locations for SOF personnel.[1,13,17,23] Despite the apparent need for research, there remains a lack of literature establishing prospectively identified risk factors for MSIs to the shoulder, especially within SOF populations. Some evidence exists for the role of several variables related to strength (eg, external/internal rotation strength and strength ratios) and movement patterns (eg, decreased upward rotation and posterior tilt and increased internal rotation of the scapula) of the shoulder.[§] However, much of this research was conducted retrospectively, leading to the inability to determine a prospective timeline between deficits or alterations in these variables and injury (ie, deficiencies/alterations came first). Further, all of it was conducted in nonmilitary populations. Therefore, the aim of the current study was to reexamine the validity of these retrospective risk factors, investigating the prediction of shoulder injuries in AFSOC personnel (ST operators) by shoulder muscle strength, ipsilateral strength ratios, bilateral strength asymmetries, and scapular kinematics during a humeral elevation task.

Our results indicated no association between strength or ipsilateral strength ratios and shoulder injury, in contrast to the findings of several previous studies.[2,3,9,18,19,28,29] The most likely explanation for these conflicting results lies in the difference in populations. The majority of previous studies have investigated the effects of strength or strength ratios in "overhead athlete" populations, such as baseball,[3] volleyball,[28] water polo,[19] and handball players.[9] The remaining studies have used samples taken from the general population, either recreationally active or occupationally active individuals.[2,18,29] As mentioned before, the musculoskeletal, biomechanical, and physiological demands of these populations are not comparable with the demands of ST operators. For example, overhead athletes would most likely perform more frequent and dynamic overhead movements, with variable movement patterning such as a spiking motion in volleyball athletes. These movement patterns are not often performed by ST operators, who are more commonly required to perform movements related to lifting, climbing ladders/walls, and dragging objects. Further, differences in how these populations train and prepare for their respective athletic or occupational demands could affect the role that shoulder strength variables play in the development of injury.

The shoulder musculature contributes to both mobility and stability of the glenohumeral joint, providing critical functions for coordinated and safe movement of the UEs.[4,10,20,25,28] The latissimus dorsi, infraspinatus, teres minor and major, and subscapularis produce an inferior translation force to the humeral head to oppose superior translation of the head of the humerus.[19,22,28-30] Weakness or altered muscle activation in the direction of shoulder external or internal rotation, or both, can result in (1) increased superior translation of the humeral head, increasing shear and compressive forces on the rotator cuff tendons[20,25] and (2) excessive humeral head translation anteriorly, resulting in abnormalities such as biceps tendinitis or glenohumeral instability.[4,28] Despite these previous findings, our results indicate that shoulder muscle strength and ipsilateral strength ratios are not significant risk factors for shoulder injury in SOF populations. However, our results do not indicate the role that altered patterns of shoulder muscle activation during functional activities may have played in the occurrence of injury. As discussed above, this has also shown a retrospective association with some shoulder conditions and is therefore a potential area of focus for future research.

This was the first study to investigate the role of bilateral strength asymmetries of UE musculature with MSI, showing results contrary to those of previous studies addressing asymmetries of the LE musculature and injury.[22,31] Previous authors have proposed that overreliance on a stronger limb may place more repetitive and greater torques, and therefore more overall stress, on the capsuloligamentous structures of the respective limb.[22,31] Further, an individual may overestimate the strength of the contralateral, weaker limb, engaging in movements or behaviors that impose greater impact forces than the limb can accommodate.[22,31] However, the results of the current study provide some evidence that these theories do not hold for the UEs, at least in the studied population.

One possible explanation for our results is that for the LEs, both limbs are frequently active at the same time and

[§]References 2, 3, 5-9, 12, 15, 16, 18-20, 26-29.

work together to complete common movement tasks (ie, standing, walking, jumping, climbing). For UE movement, we propose, anecdotally, that the frequency of bilateral movements is lower, although no empirical evidence is available to support this. Therefore, strength asymmetries may not predispose an individual to the increased joint strains observed in the LEs. Another possible explanation is that the UEs are exposed to unique demands compared with the LEs; the UEs spend less time in weightbearing positions and therefore less frequently experience the type of high-impact forces that commonly cause LE MSIs. Therefore, while the rates of shoulder injury are still high in comparison with the LEs, the underlying loads and impacts that cause injuries to these two different structures differ greatly, leading to a unique risk factor profile for each. While these explanations are plausible, more research is needed to confirm the findings of the current study, given that it is the first to explore the relationship between strength asymmetries and shoulder MSI.

Our results indicated there was no association between scapular kinematics during humeral elevation and the development of shoulder injuries, also contrary to a number of previous reports.[15,16,26,27] Optimal positioning of the scapula and movement control is thought to be important for normal shoulder function.[10] For example, impingement of the shoulder has been attributed to inadequate upward rotation and posterior tilt of the scapula during the humeral elevation.[10,15,16] However, as discussed for strength variables, all previous studies on scapular kinematics and shoulder MSIs have been conducted retrospectively and in differing populations.[15,16,26,27] Further, the retrospective timeline is even more troublesome for kinematic variables, given the higher likelihood that the shoulder conditions, proposed as an outcome, would create abnormal, compensatory movement patterns.

ST operators, as part of the SOF, are exposed to unique musculoskeletal and physical demands. Therefore, while this study presents novel results important to the field of sports medicine, caution should be used when generalizing them to populations outside of the SOF. Another limitation of the current study is that we did not obtain measures of shoulder mobility and flexibility, which have been demonstrated to be associated with shoulder conditions in civilian populations.[28,29] Most notably, studies have noted limited internal range of motion in individuals with active forms of shoulder impingement syndrome.[28,29] However, given that shoulder impingement is characterized by a lack of shoulder mobility, we felt that these studies do not provide strong support for its role as a prospective risk factor for all shoulder MSIs. Finally, it was not possible to control for training and activity levels across the operators, which could have influenced the relationship between the studied variables and subsequent injury. However, we argue that the interparticipant differences in training and activity were most likely small, given that all participants were under the same military occupational specialty and operated out of the same base.

Related to the strengths of this work, the findings of our study hold significant practical applications for clinicians working with SOF personnel. Based on our results, clinicians working with SOF personnel should be wary of using strength or movement quality screenings in assessing the risk for shoulder injury in their clients. While these screenings may hold value in identifying whether shoulder dysfunction is already present, they do not appear to hold any predictive value for future shoulder injuries or conditions.

CONCLUSION

Results of the current study indicate that shoulder muscle strength, ipsilateral strength ratios, bilateral strength asymmetries, and scapular kinematics were not predictive of future MSIs to the shoulder in SOF personnel. These variables were selected based on previous literature demonstrating some associations between these variables and shoulder injuries and conditions in nonmilitary populations. Further, they were selected based on being modifiable through training or therapy and therefore having a high clinical impact if shown to be related to the development of shoulder injuries. However, this is the first prospective study to address these as potential risk factors in a military population, and it is the first study to address some of the variables in any population. Therefore, while replication is needed in future research, we propose that these results hold the best evidence for guiding researchers and clinicians in the treatment and study of MSIs to the shoulder.

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