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Systematic Review

Isokinetic Shoulder Strength and its Associations to Injury in Tactical Populations: A Critical Review

MICHAEL S. WILKINSON†[1], JOSHUA H. GUY‡[1], and STEVEN J. OBST‡[2]

[1]School of Health, Medical, and Applied Sciences, Central Queensland University, Cairns, QLD, AUSTRALIA; [2]School of Health, Medical, and Applied Sciences, Central Queensland University, Bundaberg, QLD, AUSTRALIA

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 17(3): 235-251, 2024. The aim of this review is to evaluate existing isokinetic testing protocols for the shoulder in tactical occupations, document their shoulder strength profiles, and determine any associations to shoulder injury. Four electronic databases were searched (Medline/Pubmed, Ovid/Emcare, CINAHL/Ebsco and Embase) using the keywords police OR law enforcement, firefighter, military, AND isokinetic. Articles were eligible if they had at least one cohort of a tactical population and included isokinetic testing of the glenohumeral joint. The search yielded 275 articles. After screening for duplicates and inclusion criteria, 19 articles remained for review, six of which assessed injury correlation. 17 articles evaluated military personnel and two examined firefighters. Articles were categorized by study design, population, isokinetic protocols, strength outcome measures and statistical measures. Concentric internal rotation (IR) and external rotation (ER) strength at 60 degrees/second were reported most frequently (84% of cases). There was a paucity of testing speeds, repetition ranges and contraction types evaluated when compared to existing literature in other populations with high shoulder injury occurrence such as overhead and collision athletes. Outside of military cohorts, there is limited data available to characterise the isokinetic strength profile of the shoulder in tactical occupations. Meta-analysis for injury association was unable to be performed due to independent variable and statistical heterogeneity. However, a best evidence synthesis suggested conflicting evidence to support the association of injury with isokinetic strength testing in tactical populations. Future studies should prioritise prospective designs utilising variable speeds, repetition schemes and contraction types to better capture the dynamic occupational demands in tactical groups.

KEY WORDS: Military, firefighter, injury risk, glenohumeral joint, dynamometry

INTRODUCTION

Tactical occupations, such as firefighters, military personnel, and police officers perform highly physical tasks in stressful and potentially life-threatening situations (12, 15, 60). As such, individuals who work within these professions have higher rates of musculoskeletal injury compared to the general population (27). This is further compounded by the need to carry and operate specialist equipment in hazardous and unpredictable situations (33) and perform quick and immediate force production from positions of relative rest (18). While the biomechanical demands of the shoulder in tactical occupations have not been well documented, high velocity and ballistic tasks have been shown to place large demands on the shoulder complex (35, 71) and occur regularly in occupational tasks such as grappling with non-compliant offenders or the beaching and demolition of structures. The general risk of shoulder injury is also compounded by the anatomical nature of the shoulder itself, as the glenohumeral joint suffers reduced stability from passive constraints when compared to other joints of the body (44). This unique combination of occupational demands and anatomical factors could lead to an increased occurrence of injuries within tactical groups where both traumatic and repetitive injuries have been documented (50, 58).

The prevalence of shoulder and upper limb injuries among tactical cohorts is accordingly high when compared to other occupations. Sprains and strains are well documented as the leading primary cause of musculoskeletal injury in each tactical occupation (39, 40, 50). However, there is little data to delineating shoulder specific injury mechanisms in each population. The causes of sprains and strains in each occupation vary widely from slips, trips and falls (50), to repetitive and forceful muscle contraction (58). Police officers have a documented upper limb injury prevalence that accounts for 33-43% of all their musculoskeletal injuries (40), with the leading cause often being related to restraining non-compliant offenders (16, 40). While Injuries in military settings trend towards repetitive strain pathologies of the lower limb (59), the occurrence of shoulder instability and dislocation has been documented at ten times the incidence compared to the general population (51). Military special forces also incur higher rates of shoulder injury when compared to their regular military counterparts (32). Within U.S. Navy SEAL populations the upper extremity and shoulder accounted for 38% of their musculoskeletal injury burden (39). Similarly, in U.S. Army Special Forces the shoulder accounts for 23.1% of all reported injuries (4). In firefighting populations shoulder injuries account for 14% of their musculoskeletal injury profile secondary to lower back and knee injuries (50). Physical demands and training are also suspected as contributing factors in tactical injuries (4), though it is not clear how physical characteristics, such as strength and endurance profiles, may predispose injury in these occupational settings.

There is a relative paucity of data regarding the specific costs associated with shoulder injuries in tactical populations. However, general musculoskeletal injuries in tactical professions are substantial with workers compensation costs up to $57,106 USD per claim (40, 50). The associated work-time loss is also significant, with compensation claims among tactical groups being longer than reported national averages in the U.S. (27). Given the economic cost and time loss burdens associated with injuries among tactical occupations and the high relative rates of shoulder injury, it is important to identify what risk factors are relevant within these populations and what assessment tools could be used to mitigate risk.

Numerous screening tests have been used to quantify injury risk in tactical occupations, with most studies using field-based strength and fitness measures. Two previous systematic reviews in tactical populations reported an elevated overall injury risk with poor metabolic and aerobic fitness testing (36, 66). However, neither study was able to link poor performance to region-specific injury. Similar findings were reported for upper limb specific tests, such as push ups, pull ups, and grip strength testing, which were prognostic only of general injury risk (37, 65). However, research in populations with high shoulder injury incidence such as overhead and collision athletes demonstrate risk of shoulder specific injury based on detailed isokinetic strength assessment (21, 25, 67, 68). In addition to isokinetic internal (IR) and external rotation (ER) strength, specific ratios of concentric ER divided by concentric IR (ER/IR ratio) and concentric IR divided by eccentric ER (functional deceleration ratio/FDR) have been shown to be either protective or predictive of shoulder injury (11, 23). Specifically, altered ER/IR ratios are associated with shoulder instability and impingement when below 66% (69) which has led to recommendations of ER strengthening programs to prevent shoulder injury (23). The ER/IR ratio is also unique in it should remain constant at multiple isokinetic velocities (23). While the functional requirements of overhead and collision athletes and tactical populations differ, the prognostic value of isokinetic shoulder assessment in these athletic groups makes it an obvious starting point for risk assessment in tactical occupations. Use of isokinetic shoulder testing in tactical populations is limited primarily to military personnel where shoulder injury association has been linked with ER and IR strength and altered ER/IR ratios (20, 53, 55, 61). It's use in other tactical populations, such as police and firefighters, is minimal and the protocols vary considerably between studies. Therefore, the aims of this review are to report on the existing isokinetic protocols used within tactical occupations, outline the isokinetic strength profile of the shoulder in these groups, and determine any association between isokinetic strength and shoulder specific injury.

METHODS

Protocol

This review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines (52) and registered with PROSPERO (# CRD42021278014). A systematic search of four electronic databases (Medline/Pubmed, Ovid/Emcare, CINAHL/Ebsco and Embase) was conducted on February 14th, 2022. The search strategy consisted of the following combination of search terms: (police OR law enforcement OR firefighter OR military) AND (isokinetic). Inclusion of "shoulder" as a key term limited retrieved results on pilot searches as most studies did not include it as a MeSH term. As such, it was not included in the final search strategy. Specific search strategies for each database are included in Table 1. All eligible records were exported into Endnote X9 (64). This research was conducted in line with the ethical standards put forward by the International Journal of Exercise Science (47).

Inclusion criteria for this review involved: 1) having at least one subgroup from police officers, firefighters, or military personnel; 2) including measurements of isokinetic strength obtained using isokinetic dynamometry of the glenohumeral joint. Only full text articles available in peer reviewed journals were included in the final review. No limits were sets on publication dates or language.

Table 1. Specific database search strategies.

Database	Search String
Medline/Pubmed	(police OR law enforcement OR firefighter OR military) AND (isokinetic)
Ovid/Emcare	((exp police/) OR (law enforcement/) OR (exp firefighter/) OR (exp military/) AND exp isokinetic
CINAHL/Ebsco	(police OR law enforcement OR firefighter OR military) AND (isokinetic)
Embase	('police'/exp OR police OR 'law enforcement'/exp OR 'law enforcement' OR (('law'/exp OR law) AND enforcement) OR 'firefighter'/exp OR firefighter OR 'military'/exp OR military) AND isokinetic

Appraisal of the methodological quality of the included studies was performed independently by two of the authors (MW and JG) using the AXIS tool (17). The AXIS is a 20-question survey used to evaluate research reporting quality of cross-sectional studies. While several studies did not utilize cross-sectional designs (2, 6, 20, 32, 46, 62), the AXIS tool was still implemented to provide an equitable comparison between studies. Each question on the AXIS is scored as either 'yes', 'no', or 'do not know'. Questions 7, 13, and 14 were considered not applicable to this review based on study design and population, and were removed, leaving a total of 17 questions. The AXIS does not have its own scoring system. As such, studies were given a percentage score based on the results of the 17 included questions (Table 2). Answering 'yes' to a question resulted in scoring 1 point while answering 'no' or 'do not know' resulted in 0 points. The exception to this was question 19 relating to conflicts of interest where answering 'yes' or 'do not know' resulted in 0 points and answering 'no' resulted in 1 point. These modifications to the AXIS tool have been used in previous reviews examining isokinetic dynamometry with observational study designs (10). Prior to the formal grading process, both reviewers met to establish agreement on the interpretation of each question and piloted the scoring of three articles. Cohen's Kappa (*k*) after this pilot process was calculated as 0.94 (near perfect). After discussion, further consensus was established between the interpretation of question 19 and no further disagreement occurred requiring mediation through the third author (SO).

Grading of research quality was also evaluated using the Critical Appraisal Score (CAS) (29) and based on the results of the AXIS tool. The grading system assigns studies to categories based on the converted percentage score from methodological appraisal using the AXIS. Studies categorized as 'good' require a score of > 60%, 'fair' require a score of 45-59%, and 'poor' score < 45%. Studies were also classified according to the Australian National Health and Medical Research Council's (NHMRC) recommendations (48). This grading system classifies studies based on their methodology and study design, with the highest level of evidence (level I) being awarded to systematic reviews of randomized controlled trials, and the lowest level of evidence (level IV) being case series (48).

Statistical Analysis

Extracted data was summarised in table form according to the following categories: study design, population, isokinetic testing protocol variables (position, speed, contraction type and repetitions), outcome measures for strength testing (strength values and ratios), and summary and test statistics including odds ratios (OR) for injury association. Where appropriate, studies that reported normalized strength data using multiple subgroups (e.g., left/right and dominant/non-dominant limbs and good/poor performance) were combined into a pooled mean and standard deviation according to the formula from the Cochrane Handbook for Systematic Reviews of Interventions (30). Studies including subgroups with heterogenous populations of interest (e.g., male and female, injured and non-injured) were not pooled for the purposes of this review. Studies presenting bodyweight normalized strength data (Nm/kg) as whole number percentages were converted to decimal values to better allow comparison between studies.

Due to study heterogeneity with independent variable selection and statistical test selection, meta-analysis of injury association was not performed. Instead, the strength of evidence for the association of shoulder strength and injury risk was graded using a best evidence approach according to five criteria, where study quality was defined using the CAS classification of the AXIS score (10, 56).

1. Strong evidence: two or more studies with high quality and generally consistent findings across all studies (> 75% of the studies reported consistent findings).
2. Moderate evidence: one study with high quality and/or two or more studies with low quality, and generally consistent findings in all studies (> 75% of the studies reported consistent findings).
3. Limited evidence: only one study with low quality.
4. Conflicting evidence: inconsistent findings in multiple studies (< 75% of the studies reported consistent findings).
5. No evidence: when no studies could be found.

RESULTS

275 articles were identified from the initial search, with 127 being removed through duplicate screening (Figure 1). Of the remaining 148 articles, 106 were removed after title and abstract screening. Of these remaining 42 articles, 14 met inclusion criteria and were included in the review. The reference lists of the 14 included articles were screened based on title and abstract. This process identified five further articles, resulting in a total of 19 articles being included in the final review.

All studies evaluated scored 'good' in accordance with Critical Appraisal Scoring guidelines, exceeding 60% on the AXIS tool. The average AXIS score across studies was 83%. Areas where studies scored poor on the AXIS included sample size justification (question 3), internal consistency (question 15), and declaring conflicts of interest (question 19). Only one study justified their sample size for power calculations (26). No studies reported statistical methods for determining internal consistency. As such, all studies received a score of 0 on question 3 of the AXIS. Unless a study specifically declared there was no conflict of interest, question 19 was marked as "do not know" and the study received a score of 0. Only five studies explicitly declared if there were conflicts of interest (20, 26, 38, 49, 61).

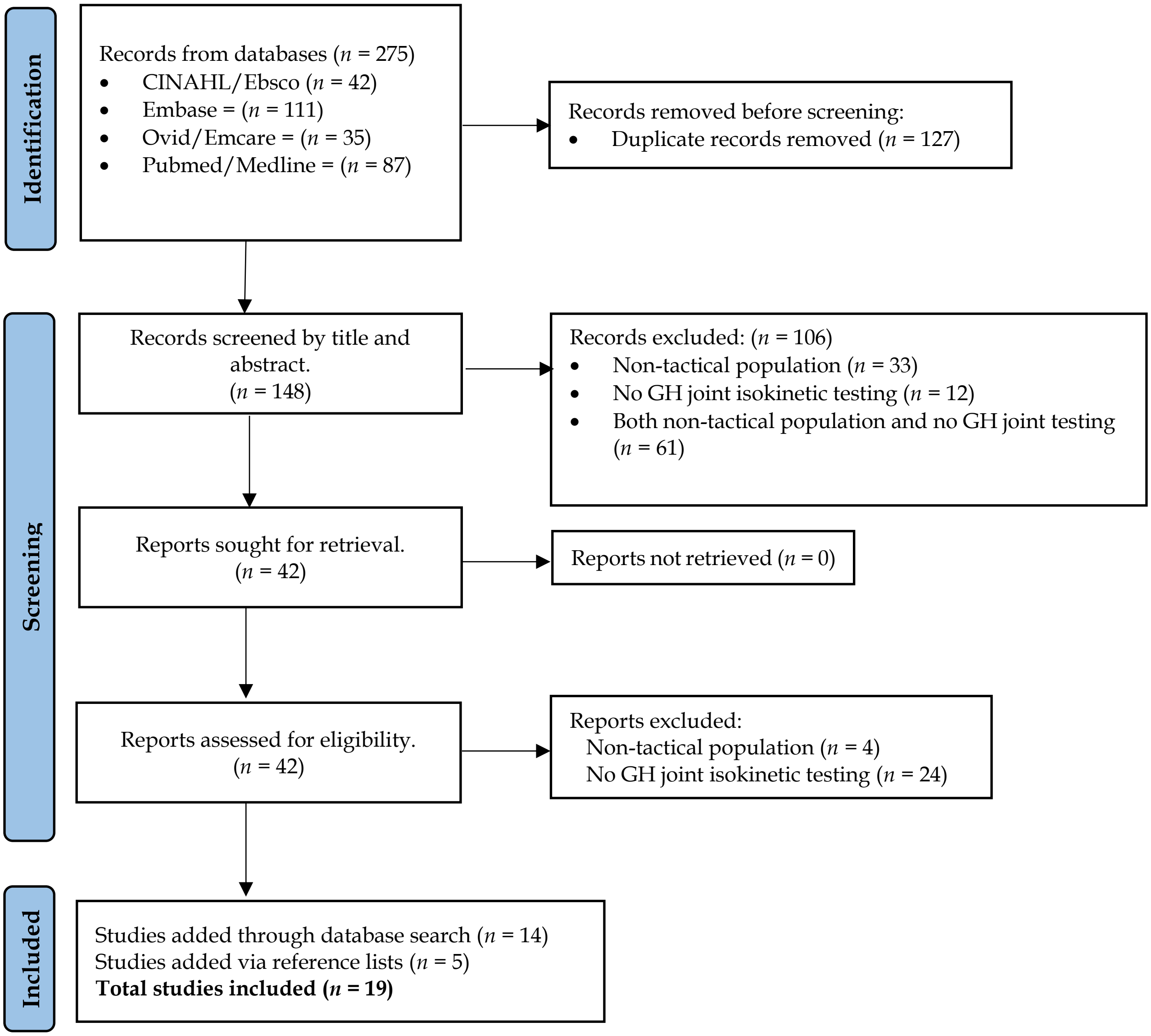

Figure 1. PRISMA flow diagram.

Study characteristics are included in Table 2. Of the 19 studies included in the review, 13 were cross-sectional (3, 7, 8, 14, 26, 38, 46, 49, 53-55, 62, 70), three were prospective cohorts (6, 32, 46), two were retrospective cohorts (20, 61), and one was a controlled trial (2). NHMRC level of evidence for each individual study is included in Table 2.

A total of 3332 participants were enrolled across the 19 studies. Two studies included firefighters (*n* = 140) (38, 49). All other studies included military personnel with a total of 3192 participants. No studies involved police officers. Of the military studies, six involved U.S. Marines (6, 7, 20, 54, 55, 70), six involved U.S. Army Airborne Soldiers (3, 8, 14, 45, 46, 62), two included U.S. Navy SEALs (2, 61), one included U.S. Army Special Forces (53), one included U.S. Air Force Special Forces (32), and one included Brazilian Army soldiers (26).

Table 2. Study characteristics.

Author (Year)	Population	Sample Size	Study Design	AXIS Score	Level of Evidence
Abt et al. (2016)	US Army Airborne Soldiers	253	Cross-sectional	76%	III-3
Abt et al. (2016)	US Navy SEALs	85	Control Trial	82%	III-2
Allison et al. (2015)	US Army Airborne Soldiers	406	Cross-sectional	82%	III-3
Allison et al. (2017)	US Marines	62	Prospective Cohort	82%	II
Allison et al. (2019)	US Marines	294	Cross-sectional	82%	III-3
Crawford et al. (2011)	US Army Airborne Soldiers	99	Cross-sectional	76%	III-3
Eagle et al. (2018)	US Marines	310	Retrospective Cohort	82%	III-3
Goncalves et al. (2018)	Brazilian Army Soldiers	50	Cross-sectional	94%	III-3
Johnson et al. (2019)	US Special Forces	140	Prospective Cohort	82%	II
Lindberg et al. (2014)	Swedish Firefighters	38	Cross-sectional	88%	III-3
Nagai et al. (2016)	US Army Airborne Soldiers	35	Cross-sectional	82%	III-3
Nagai et al. (2017)	US Army Airborne Soldiers	275	Prospective Cohort	82%	II
Noh et al. (2020)	Korean Firefighters	102	Cross-sectional	88%	III-3
Parr et al. (2015)	US Army Special Forces	88	Cross-sectional	82%	III-3
Poploski et al. (2018)	US Marines	195	Cross-sectional	82%	III-3
Poploski et al. (2020)	US Marines	247	Cross-sectional	82%	III-3
Sell et al. (2010)	US Army Airborne Soldiers	404	Cross-sectional	82%	III-3
Sell et al. (2016)	US Navy SEALs	176	Retrospective Cohort	88%	III-3
Winters et al. (2019)	US Marines	73	Cross-sectional	82%	III-3

Seven studies reported their isokinetic testing position as seated with between 15 to 45 degrees of shoulder abduction and 15 to 20 degrees of shoulder flexion (14, 20, 26, 38, 54, 55, 61). All other studies either did not report their testing positions or deferred to manufacturer's guidelines without explicitly reporting them. In studies where this was the case, an attempt was made to evaluate the manufacturer's manual for more detail. However, in all cases multiple testing positions were noted for the shoulder, leaving the exact position unknown.

Two studies did not report the contraction type used during testing (6, 49) while the remaining 17 studies reported utilising a concentric-concentric testing protocol. 15 of the military studies utilized testing speeds of 60 degrees per second (°/sec) (2, 3, 6, 8, 14, 20, 26, 32, 45, 53-55, 61, 62, 70) while two did not report their testing speed (6, 45). Only one military study did not report how many repetitions they utilised during isokinetic testing (6), with all others using 5 repetitions on IR and ER. Both studies on firefighters utilized testing speeds of 60°/sec and 180°/sec (38, 49) with repetition schemes of 5 and 15, respectively, for both flexion and extension. Only one study reported the range of motion limits for isokinetic testing as within the available active range of motion for each participant (61).

A summary of isokinetic testing protocols is listed in Table 3. All military studies except one (26) reported testing isokinetic ER and IR (2, 3, 6-8, 14, 20, 32, 45, 46, 53-55, 61, 62, 70). The two studies on firefighters (38, 49) and one study on Brazilian army soldiers (26) reported assessing flexion and extension. One study reported evaluating adduction and abduction (8).

Table 3. Isokinetic testing protocols.

Author (year)	Testing Position	Movement Tested	Speed	Contraction	Repetitions
Abt et al. (2016)	NR	ER/IR	60°/sec	Con	5
Abt et al. (2016)	NR	ER/IR	60°/sec	Con	5
Allison et al. (2015)	NR	ER/IR ADD/ABD	60°/sec	Con	5
Allison et al. (2017)	NR	ER/IR	NR	NR	NR
Allison et al. (2019)	NR	ER/IR	60°/sec	Con	5
Crawford et al. (2011)	Seated 30° ABD	ER/IR	60°/sec	Con	5
Eagle et al. (2018)	Seated 45° ABD, 15° FF	ER/IR	60°/sec	Con	5
Goncalves et al. (2018)	Seated	FF/EXT	60°/sec	Con	5
Johnson et al. (2019)	NR	ER/IR	60°/sec	Con	5
Lindberg et al. (2014)	Seated 70° trunk incline	FF/EXT	60°/sec 180°/sec	Con	5 15
Nagai et al. (2016)	NR	ER/IR	NR	Con	5
Nagai et al. (2017)	NR	ER/IR	60°/sec	Con	5
Noh et al. (2020)	NR	FF/EXT	60°/sec 180°/sec	NR	5 15
Parr et al. (2015)	NR	ER/IR	60°/sec	Con	5
Poploski et al. (2018)	Seated 15-20° ABD, 15-20° FF	ER/IR	60°/sec	Con	5
Poploski et al. (2020)	Seated 15-20° ABD, 15-20° FF	ER/IR	60°/sec	Con	5
Sell et al. (2010)	NR	ER/IR	60°/sec	Con	5
Sell et al. (2016)	Seated 15° ABD, 15° FF	ER/IR	60°/sec	Con	5
Winters et al. (2019)	NR	ER/IR	60°/sec	Con	5

NR = not reported EXT = extension
ABD = abduction ER = external rotation
ADD = adduction IR = internal rotation
FF = forward flexion Con = concentric

Isokinetic strength data were reported using various metrics (Table 3). Three studies reported peak torque (Nm) (7, 26, 49), while 15 studies reported torque normalized to bodyweight, expressed as %BW (2, 3, 6, 8, 14, 20, 45, 46, 61, 62, 70) or Nm/kg (32, 53-55). One study reported strength in Watts per kilogram (W/kg) (38). Another study reported total work in Joules (J) (49). Six studies reported the ratio of ER to IR strength (ER/IR ratio) (2, 3, 8, 32, 53, 62). Thirteen studies reported bodyweight normalized ER and IR strength data as multiple subgroups, and where appropriate, these were collapsed into single study means and standard deviations presented in figure 2 as a forest plot (2, 3, 6-8, 14, 32, 46, 53-55, 61, 62, 70).

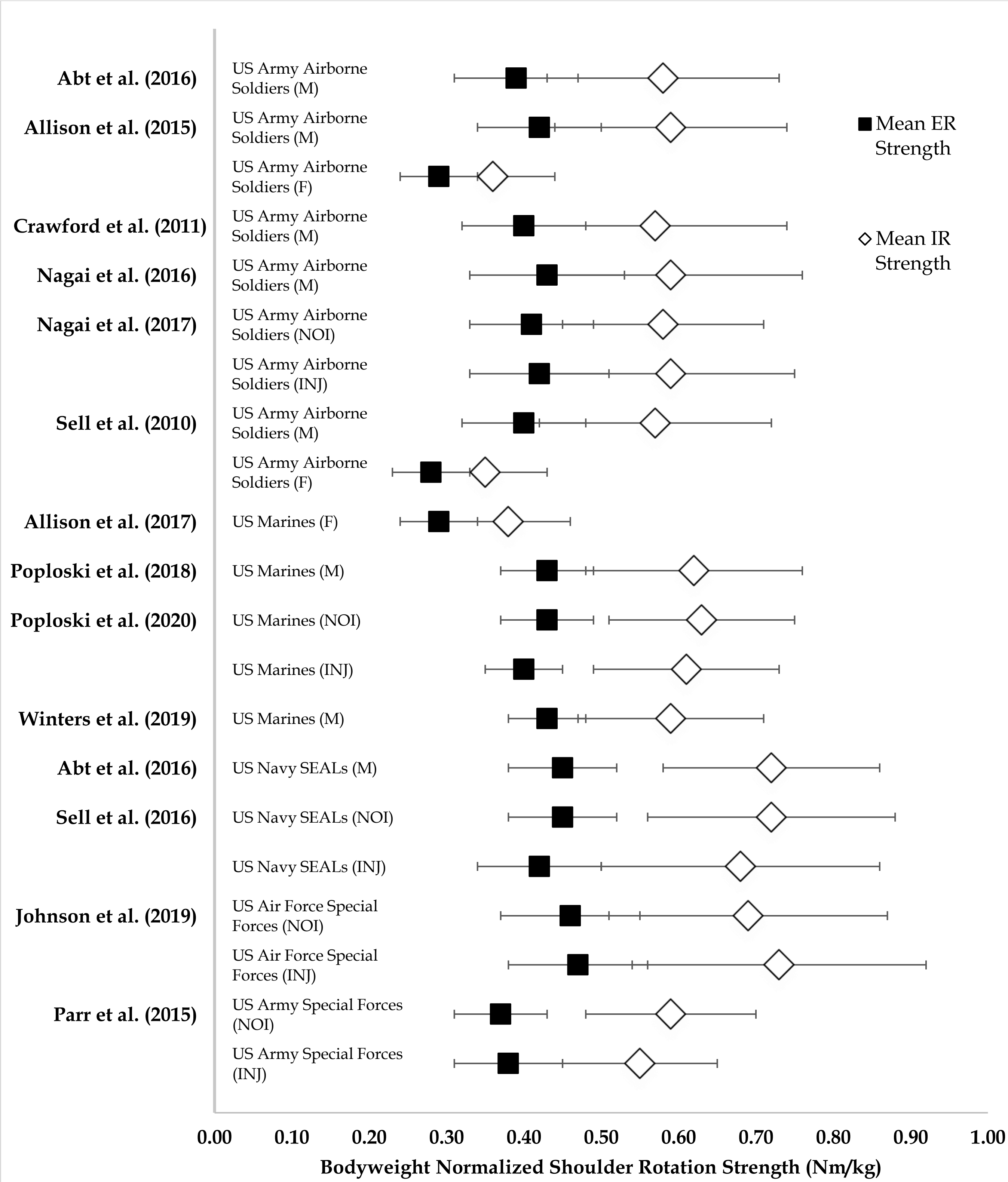

Figure 2. Bodyweight normalized MVCC strength.

M = male NOI = non-injured group
F = female INJ = injured group

DISCUSSION

This critical review aimed to provide a comprehensive synthesis of isokinetic shoulder testing protocols, outcomes, and associations with injury in tactical populations. We identified 19 studies that reported isokinetic shoulder strength in tactical populations. Of these, 17 included military subgroups, and 2 included firefighters. No studies included police officers or other law enforcement agents. Maximal voluntary concentric contraction (MVCC) strength at 60°/sec for shoulder ER and IR was the most frequently reported outcome. Normalised ER and IR MVCC strength was similar across studies with the most notable differences being between female and male tactical cohorts. Overall, there was conflicting evidence for an association between isokinetic shoulder strength and injury.

The isokinetic testing protocols evaluated in this review were underreported when compared to overhead and collision athletes with similarly high rates of shoulder injury (10). Most studies in this review assessed shoulder strength at a single angular velocity (60 deg/sec) over a maximum of five repetitions, limiting the potential to identify velocity and/or fatigue dependent deficits in shoulder testing (23). A previous systematic review (10) reported isokinetic studies in overhead athletes used multiple testing speeds, ranging from 30 to 300 deg/sec. They also reported repetition schemes between three and 50 where they documented the strongest correlations to injury with higher repetition IR endurance measures. Increased isokinetic testing speed is commonly associated with higher repetitions, which shifts the emphasis from absolute strength towards strength endurance where higher values have been linked to injury protection in overhead athlete groups (25, 67). In our review, repetition ranges greater than five were only used in two studies of firefighters (38, 49). No study in this review reported maximal voluntary eccentric contraction (MVEC) strength. Prior research in collision athletes has documented associations with deficits in MVEC ER and IR strength or altered ratios of MVEC to MVCC IR and ER strength to shoulder injury (21, 67). While these findings regarding MVEC may not necessarily apply to tactical populations, the lack of diversity in testing speeds, repetitions, and contraction types represents an empirical gap and overlooks important strength measures that may be useful predictors of injury risk.

While absolute muscular strength has been reported as an important variable in tactical operations, muscular endurance has also been shown as a key aspect for tactical occupation performance (41, 63). The absence of higher repetition, endurance based isokinetic testing may not allow a full risk assessment for personnel that have to hold and carry tactical equipment such as special weapons, riot gear, or firefighting equipment for longer periods of time. While specific biomechanical analysis of these tasks is not well developed in the literature, it has been previously documented hand grip significantly increase the demand on the rotator cuff musculature (5). Additionally, grip tasks in combination with isometric or dynamic shoulder loading significantly alters muscle activation patterns in the shoulder with loads as little as 0.5kg (9). Hand grip has also been documented to shift EMG activation away from the deltoid and towards the rotator cuff, which has been suggested as a possible cause of shoulder injury (71).

Upper body power has been documented as a key physical component for tactical occupations, especially in firefighters where demolition and breaching tasks are frequently required (1). As such, the inclusion of higher testing speeds would seem relevant to firefighting and military populations that perform kinetic violence on inanimate objects. Not only have injury rates been shown to increase when going from sedentary to high velocity muscle contractions without adequate warm up (57), but higher velocity arm movements have also been shown to increase EMG activation of the rotator cuff, deltoid, and pectorals muscles by up to 110% when compared to lower velocity tasks (35). Additionally, close quarters combat drills and arrest scenarios require tactical personnel to simultaneously control a resisting offender while attempting to push, pull, and otherwise manipulate them into restraint positions. These tasks require high velocity movement, reactive eccentric control, and heavy use of grip strength to prevent the operator from being overpowered further supporting the need for broader isokinetic testing protocols in tactical occupations (16).

Most studies in this review assessed bodyweight normalized shoulder ER and IR strength as their primary variable of interest. Previous research has implicated the rotator cuff as a keystone muscle group for upper limb injury prevention, with isokinetic rotation values having an overflow effect on other shoulder strength measures as they improve (23, 24). The range of values reported in this review for normalized MVCC ER and IR strength ranged from 0.28 Nm/kg (62) to 0.47 Nm/kg (32), and 0.35 Nm/kg (62) to 0.73 Nm/kg (32), respectively at 60°/sec. ER/IR ratios ranged from 0.62 (61) to 0.82 (7). Previously reported control values were 0.20 Nm/kg to 0.44 Nm/kg for ER and IR, respectively, in a combined sample of healthy men and women at 60 deg/sec (34). All tactical cohorts from this review demonstrated higher relative ER values when compared to these controls. The IR strength values from these healthy controls (34) fall within the lower range of values from this review. Consistent with the general population (31), female military personnel tended to have lower body mass normalised ER and IR strength values when compared to their male counterparts, but higher ER/IR ratios (figure 2) (6, 8, 62). Irrespective of the military subgroup, males had similar normalised ER strength with U.S. Navy SEALs and U.S. Air Force Special Forces having higher normalised IR strength (2, 32, 61) which may reflect higher levels of fitness and specialised training within these professions (54).

When comparing isokinetic strength values within this review to other populations with high rates of shoulder injury, data was limited as few studies reported bodyweight normalized strength data at matched angular velocities. However, differences in strength were apparent when data was available. Elite male handball players were reported having higher mean ER values (0.50 Nm/kg), and IR values (0.70 Nm/kg) compared to the tactical cohorts from this review (25). Elite female handball players have previously documented mean ER and IR values of 0.37 Nm/kg and 0.52 Nm/kg respectively, which were also higher than the range of values demonstrated in this review for female tactical groups (21). ER and IR strength values for elite swimmers have been reported up to 0.46 Nm/kg for ER and 0.71 Nm/kg for IR (19), which is consistent with only the higher end strength values reported for U.S. Navy Seals and U.S. Special Forces. Rugby players have previously reported ER and IR strength values similar to tactical cohorts from this review, with ER and IR values of 0.43 Nm/kg and 0.62 Nm/kg, respectively being documented (22). Overall, comparison to overhead athlete groups may not be valid despite a shared injury profile. Tactical occupations seemingly have an isokinetic strength profile that overlaps more with rugby players or other collision athletes; however, there is a relative paucity of comparable data. Only two prospective studies on rugby players were found linking injury risk with reduced isokinetic strength variables (28, 42). While both demonstrated an association between reduced MVEC IR strength, only one utilized 60°/sec with bodyweight normalized data. Further prospective research would be needed to determine shared injury risk; however, this may further support the inclusion of eccentric testing in tactical groups.

When considering the six studies examining injury correlation from this review, there was conflicting evidence for an association between isokinetic shoulder strength and shoulder injury in tactical populations. The prospective studies in this review were unable to demonstrate an association between isokinetic shoulder strength and shoulder injury. The first documented non-significant odds ratios (OR) of 1.007 (95% CI 0.978-1.037) and 1.005 (95% CI 0.987-1.023) for ER and IR strength, respectively, in male U.S. Army Airborne soldiers (46). Similar findings were reported in U.S. Special Forces Operators (32) with no significant association between injury and ER strength (OR = 1.016, 95% CI 0.973-1.016), IR strength (OR = 1.010, 95% CI 0.990-1.032), ER/IR strength ratios (OR = 0.433, 95% CI 0.147-1.276), bilateral ER strength asymmetries (OR = 1.014, 95% CI 0.944-1.089) or bilateral IR strength asymmetries (OR = 0.999, 95% CI 0.948-1.053). It is note-worthy that both injured cohorts from these studies tested higher on ER and IR strength compared to their non-injured controls. It has been previously demonstrated in other tactical populations that higher relative strength and fitness values can be associated with injury, potentially confounding assumptions around higher strength levels being protective (13, 37). This has also been documented in athletic populations where players with higher performance measures are exposed to a higher volume of training and game time leading to increased relative injury risk (43). While this may explain why higher performing individuals can incur higher injury rates, more research on exposure and training load is needed in tactical populations to comment on this association.

Two retrospective cohort studies provided moderate evidence of an association between shoulder strength and injury within this review. The first examined U.S. Navy SEALs and reported more than 20% of those with prior shoulder injury had deficits in isokinetic ER and IR strength exceeding 10% between limbs (61). This study also reported a significant difference between injured and control groups, with the previously injured group having lower ER strength ($p = 0.003$). The second documented increased odds of having previous shoulder injury in those who had greater than 20% difference in bilateral shoulder IR strength (OR = 2.5, 95% CI 1.0-5.9) among U.S. Marines (20). This effect was substantially larger in female Marines with IR strength asymmetry (OR = 15.4, 95% CI 1.4-167.2). Two cross-sectional studies also supported moderate evidence for a relationship between shoulder strength and injury risk. U.S. Army Special Forces Operators with no history of shoulder injury had significantly higher shoulder IR strength ($p = 0.05$-0.014) and lower ER/IR ratios ($p = 0.018$-0.026) when compared to the injured and uninjured shoulders of those with injury history (53). U.S. Marines with a non-dominant side shoulder injury also demonstrated significantly less IR strength (p = < 0.001, effect size = 0.832) and ER strength (p = 0.003, effect size = 0.656) on their injured side (55). While similar associations with poor ER strength, IR strength, and ER/IR ratios also exist in the athletic literature, the tactical studies lack the relative strength of evidence from the prospective athletic research. Additionally, the lack of MVEC testing in tactical groups leaves it unknown whether specific concentric/eccentric ratios such as the FDR would apply in these populations.

This review has several limitations, primarily linked to the types of studies included in the review. There were few prospective studies examining the association between shoulder strength and injury risk, limiting the strength of our conclusions. The isokinetic testing protocols used in the included studies were limited when compared to the protocols used in other populations with high shoulder injury prevalence. The absence of multiple testing speeds, contraction types and repetition variability limit the applicability of isokinetic testing to the multitude of physiological demands required of tactical occupations. The lack of reporting on testing position or range of motion limits the comparability of the strength results. Furthermore, 17 of the 19 studies included military populations, which limits the generalisability of our findings to other tactical cohorts. Minimal data was available on firefighters, and no data was available for police officers. Heterogeneity of isokinetic strength variables and statistical test selection prevented a meta-analysis.

Existing protocols evaluating isokinetic shoulder strength in tactical occupations fail to utilize the level of detail found in other populations with a high prevalence of shoulder injury. Outside of military populations, there is currently little data to characterize the isokinetic strength profile of the shoulder in tactical groups. In this review, shoulder injury was associated with poor isokinetic ER and IR strength and altered ER/IR ratios in cross-sectional and retrospective studies of tactical cohorts. However, the overall level of evidence was conflicting. As such, more prospective research is needed utilizing a broader and deeper scope of isokinetic testing for these occupations. Future studies should aim to evaluate multiple testing speeds, repetition ranges and contraction types to comprehensively identify deficits in shoulder function within these occupations. Multiple occupational tasks performed by tactical personnel require the use of high velocity and/or sustained shoulder movements which is not adequately captured in existing isokinetic testing protocols.

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