

INFLUENCE OF LIMB DOMINANCE AND SHOULDER INJURY ON STRENGTH AND EXPLOSIVE FORCE IN US MARINES

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ABSTRACT

Background: The specialized roles of many military personnel require specific skills and high physical demands, placing unique stresses on the shoulders and increasing risk of injury. As normal dominant/nondominant shoulder asymmetries have been established in military personnel, bilateral strength comparisons must be understood in context of daily physical demands to monitor patients' progress or readiness to return to duty.

Purpose: This study aims to assess bilateral differences in strength and explosive force in United States Marines with a history of dominant or nondominant shoulder pathology.

Study Design: Cross-Sectional.

Methods: A total of 52 full-duty, male US Marines with a shoulder injury within the prior year participated. Bilateral isokinetic shoulder internal (IR) and external (ER) rotation strength, and peak force (Peak Force) and average rate of force production (Avg Rate) during an explosive push-up were collected. Dominant versus nondominant side data were independently examined within each group (DOM: dominant injury, NOND: non-dominant injury). Comparison between DOM and NOND, as well as previously published CON (no history of shoulder injury) was also completed.

Results: NOND ($n = 26$) demonstrated significantly less IR ($p < 0.001$) and ER ($p = 0.003$) strength and Peak Force ($p = 0.001$) and Avg Rate ($p = 0.047$) on the injured side, while DOM ($n = 26$) demonstrated no bilateral differences in strength or push-up performance. Comparison between the three groups showed that NOND demonstrated significantly less ER strength than CON ($p = 0.022$).

Conclusions: Military personnel demonstrate asymmetric strength patterns likely due to increased demand of the dominant shoulder. US Marines with a history of injury to the nondominant shoulder performed differently than those with a dominant side injury, presenting with both strength and push-up asymmetries. They also demonstrated significant ER strength deficits compared to CON. Common clinical practice and previous literature often compare injured and uninjured limbs or injured individuals to healthy controls, but further distinction of dominant or nondominant side may provide more accurate information needed to develop targeted treatment strategies.

Clinical Relevance: Recognizing unique occupational demands and how patients may present differently with dominant versus nondominant side shoulder injuries are important considerations for ensuring accurate assessment and effective individualized rehabilitation.

Level of Evidence: 3.

Key Terms: Injury Prevention, Military Training, Physical Therapy, Rehabilitation, Shoulder

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INTRODUCTION

The year-round, high intensity, high volume training and deployment cycles required of many Special Operations Forces (SOF) personnel place them at high risk of musculoskeletal injuries.¹ During one pre-deployment work-up, approximately one-third of a United States Marine Corps Forces Special Operations Command (MARSOC) unit experienced a musculoskeletal injury or physical limitation, which is consistent with other SOF injury rates.²⁻⁴ Shoulder injuries account for approximately 23-24% of all musculoskeletal injuries in SOF personnel^{5,6} and 78% of all upper extremity musculoskeletal disorders in MARSOC operators.⁷ Such high rates of injury are similar to that which would be expected in overhead athletes^{8,9} due to the repetitive motions and extreme shoulder demands of these sports.^{10,11} Military personnel also place substantial loads on the shoulder during physical fitness, tactical training, and deployment contributing, to high rates of shoulder injuries.¹²

For athletes and military personnel, previous injury is one of the most common risk factors for future injury.¹³⁻¹⁶ This increased risk is likely influenced by many factors including changes in motion, proprioception, strength, and function following injury.¹⁷ As the rotator cuff muscles are the primary stabilizers of the glenohumeral joint,¹⁸ several studies have analyzed bilateral shoulder internal and external rotation strength deficits following unilateral shoulder injury in athletic and military populations.^{1,19-22} Internal rotation strength deficits,²² residual external rotation weakness,^{19,20} as well as no asymmetry between the injured and uninjured shoulders^{1,21} following return to full activity have all been reported in different studies. While these inconsistencies may be influenced by differences in study populations and varying assessment protocols, comparison is often made between injured and uninjured limbs without consideration of limb dominance.^{1,21-24} As normal dominant/nondominant shoulder asymmetries have been established in uninjured athletes and MARSOC personnel,²⁵⁻²⁸ bilateral comparisons must be understood in context of daily physical demands to monitor patients' progress, deficits, or readiness to return to duty. Without limb dominance consideration and/or control group comparison, results may not accurately describe residual deficits or adaptations.

In addition to standardized strength measures, activity-specific functional assessments are encouraged for highly active individuals following injury.^{29,30} For athletes, this may include assessment of pitching mechanics or swimming stroke, or other sport-specific tasks. For military personnel, an assessment that represents the explosive requirements of modern military physical and tactical training and deployments should be considered.³¹ Asymmetries in functional performance on an explosive push-up have been found in healthy MARSOC personnel,²⁸ therefore, those with a history of dominant or non-dominant side shoulder injuries may perform differently on such task if not fully recovered.

With high tempo training cycles, any lingering deficits may be detrimental to operational readiness and increase the risk of sustaining a more severe reinjury. Shoulder strength and functional asymmetries have been established in healthy MARSOC personnel,²⁸ however, the relationship between performance and limb dominance in those with previous shoulder injury needs to be understood to provide clinicians with a more complete understanding of potential deficits and ways to better treat these individuals. Therefore, this study aims to assess differences in shoulder strength and explosive force in MARSOC personnel with a history of dominant or nondominant shoulder pathology. The authors hypothesize that asymmetries in strength and explosive force will differ between those with a history of dominant versus nondominant shoulder injuries. Additionally, the authors hypothesize that identified deficits will be greater than observed in MARSOC personnel with no history of shoulder injury.

METHODS

Participants

Participants in this study were male US Marines extracted from a larger longitudinal study from August 2015 to December 2017. Participants included MARSOC Operators as well as students and selectees in training to become MARSOC Operators. All participants were full-duty, indicating they were cleared for full and unrestricted participation in physical and tactical training. Participants were advised to limit strenuous physical training and avoid caffeine, nicotine, and alcoholic beverages twenty-four

hours prior to testing. Approval was obtained for all research procedures from the University's Institutional Review Board. Written informed consent was obtained from each subject prior to participation in the study.

Injury History

All participants were interviewed by an experienced clinical researcher and asked to describe all musculoskeletal injuries ever sustained that required the individual to stop or modify training for at least one full day, to include any injury to the musculoskeletal system (bones, ligaments, muscles, tendons, etc.) that caused the participant to stop or modify training or physical activity for at least one day, regardless if medical attention was sought. Demographic and descriptive injury data were directly entered into a customized online survey application, Research Electronic Data Capture (REDCap)³² hosted at the university during each interview. REDCap is a secure, web-based application designed to support data capture for research studies, providing 1) an intuitive interface for validated data entry; 2) audit trails for tracking data manipulation and export procedures; 3) automated export procedures for seamless data downloads to common statistical packages; and 4) procedures for importing data from external sources. Collected injury data included descriptions of anatomical location, anatomical sub location, mechanisms of injury, treatment received for injury, and if they were currently experiencing pain/modifying training due to the injury.

Laboratory Data

Shoulder Strength

Shoulder internal and external rotation were evaluated bilaterally on an isokinetic dynamometer (Biodex Medical Systems, Shirley, NY).³³ Isokinetic strength testing on the Biodex has been found to be a reliable and valid strength measure.³⁴ Participants were seated with shoulders placed in a modified neutral position of 15-20° abduction and 15-20° flexion (Figure 1). Participants were positioned and stabilized according to manufacture specifications. Warm-up and familiarization trials were performed as standard procedure as previously described.³⁵ Strength was determined by averaging five maximal repetitions and analyzed relative to body weight.



Figure 1. *Shoulder internal and external rotation isokinetic strength assessment.*

All contractions were concentric-concentric at 60 degrees/second. Side-to-side deficits were calculated by dividing (injured side/uninjured side) × 100.

Dynamic Shoulder Function

To evaluate dynamic shoulder function, participants performed an explosive push-up task (Figure 2). Participants started in a prone position with the elbows bent and each hand placed on a separate force plate (Type 9286BA, 60 cm × 40 cm platform; Kistler Instrument Corp., Amherst, NY) at approximately chest level. The force plates were mounted flush with surrounding custom-built flooring, so feet and hands were level. Participants were instructed to keep both back and legs straight, feet together, and elbows in a neutral position. When the researcher instructed “rise-up,” the participant lifted his chest approximately one inch off the ground. Once this position was attained and held for one second, the researcher instructed “go,” at which time the participant performed an explosive push-up, pushing completely off the force plates. The participant was instructed that the goal of the task was to perform

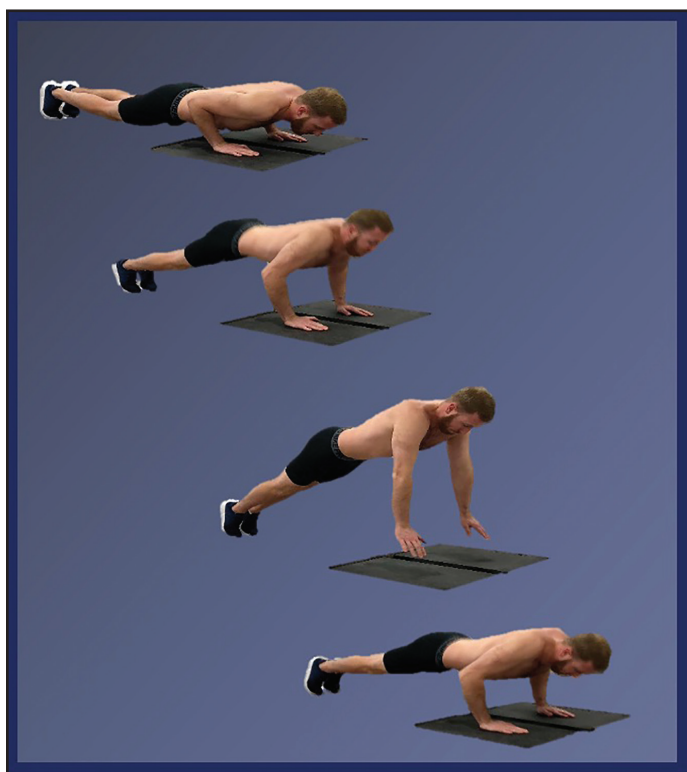


Figure 2. *Explosive push-up task.*

the most explosive push-up possible. Participants were given at least one practice trial, followed by three collected trials. A similar protocol has previously been described with excellent relative reliability ($ICC = 0.91-0.96$).³⁶

Vertical ground reaction force (VGRF) data were collected at 1200 Hz using Vicon Nexus Software (Vicon Motion Systems, Centennial, CO). VGRF analog signals were low-pass filtered with a Butterworth fourth-order zero-phase-shift lag with 50 Hertz cut-off using C-Motion Visual 3-D (C-Motion, Germantown, MD). All data processing was completed in C-Motion Visual 3-D and output variables included peak VGRF (Peak Force) during the concentric phase of the push-up movement and average rate of force production (Avg Rate). Avg Rate was defined as the rate of change in the force between the start of the movement and the peak force and was calculated as the mean of the first derivative of the VGRF. The three trials were averaged for each variable (Peak Force and Avg Rate) for each side and normalized to body weight by dividing by mass.

Subject Classification

REDCap injury data was queried based on “shoulder” location. Shoulder injuries included conditions such as sprains, strains, labral tears and fractures affecting the shoulder joint, scapula, and/or clavicle but not contusions or lacerations. Marines reporting a shoulder injury causing current pain and/or modification of training within the prior year were classified into the injured group (INJ). Participants were then further differentiated into those that reported a dominant side injury (DOM) and those that reported a nondominant side injury (NOND). Previously published data from MARSOC personnel with no history of shoulder injury, served as a control comparison group (CON).²⁸ Marines with history of bilateral shoulder injury, regardless of timing of injuries, or surgical intervention were excluded. Participants with only unilateral strength data were also excluded.

Statistical Analysis

Descriptive statistics were calculated for demographic, strength, and push-up variables. All variables were assessed for normality and frequency distribution. Paired-samples *t*-tests for parametric data and Wilcoxon Signed Ranks Tests for nonparametric data were used to compare dominant to nondominant sides within each group. Independent samples *t*-tests or Mann-Whitney U tests were used as appropriate to compare INJ to CON (injured side compared to dominant side of healthy group). One-Way ANOVA or Kruskal-Wallis One-Way ANOVA with post-hoc Bonferroni analyses were used as appropriate to compare DOM, NOND, and CON. Effect sizes (Cohen's *d* for paired and independent samples *t*-tests, $r = Z/\sqrt{N}$ for Wilcoxon Signed Ranks and Mann-Whitney U tests, η^2 for One-Way ANOVA, and ϵ^2 for Kruskal-Wallis One-Way ANOVA) were also calculated. For consistency, medians and interquartile ranges are presented in all figures. An alpha level of 0.05 was set a priori to denote statistical significance for all comparisons. Statistical analyses were performed using IBM SPSS Statistics Version 22 (IBM Corp, Armonk, NY).

RESULTS

A total of 52 full-duty, male MARSOC personnel with a history of a shoulder injury (age: 26.76 ± 3.95

years; height: 179.92 ± 6.05 cm, mass: 84.89 ± 8.62 kg) were included in the analysis. Twenty-six participants reported a dominant side shoulder injury and 26 reported a nondominant side injury. Demographic information for each group, as well as the previously published CON ($n = 195$), are presented in Table 1.

INJ demonstrated significantly less ER strength (4.88% deficit; $p = 0.012$; $d = 0.370$) and Avg Rate (5.50% deficit; $p = 0.024$; $d = 0.381$) on the injured side compared to the uninjured side, but no difference in IR strength ($p = 0.159$) or Peak Force ($p = 0.058$). When comparing the dominant side of CON to the injured limb of INJ, those with a history of shoulder injury were significantly weaker in IR (6.45% deficit; $p = 0.023$; $r = 0.146$) and ER (7.23% deficit; $p = 0.003$; $d = 0.483$) strength, but no differences in push-up variables were found (Figure 3, Full summary – Appendix 1).

Side-to-side comparisons within NOND revealed bilateral asymmetry patterns (Figure 4, Full summary – Appendix 2). NOND demonstrated significantly less IR strength (12.9% deficit; $p < 0.001$; $d = 0.832$), ER strength (9.76% deficit; $p = 0.003$; $d = 0.656$), Peak Force (3.59% deficit; $p = 0.001$; $d = 0.920$) and Avg Rate (4.49% deficit; $p = 0.047$; $d = 0.476$) on the injured side compared to uninjured side. DOM demonstrated no bilateral differences in strength or push-up variables (all $p > 0.05$). As previously reported CON demonstrated significantly less IR strength (6.45% deficit; $p < 0.001$; $r = 0.482$) and Peak Force

(1.48% deficit; $p = 0.037$; $r = 0.224$) on the nondominant side but symmetrical bilateral ER strength ($p = 0.137$) and Avg Rate ($p = 0.899$).²⁸ No significant between group differences were found when comparing CON, DOM, and NOND dominant side variables ($p > 0.05$). Nondominant side comparison between the three groups showed that NOND demonstrated 9.76% less ER strength than CON (One-Way ANOVA: $p = 0.022$; Bonferroni post-hoc analysis between NOND and CON: $p = 0.022$; $\eta^2 = 0.031$).

DISCUSSION

Due to the upper body demands of training and missions, MARSOC personnel are at high risk of shoulder injuries.^{7,37} The initial analysis of all injured individuals revealed significant strength deficits compared to individuals with no history of shoulder injury, but mixed bilateral performance asymmetries. Though a convenient and common analysis,^{1,21-24} comparing injured/uninjured groups or injured/uninjured limbs does not account for differences due to limb dominance. Therefore, the main purpose of this study was to determine if consideration of limb dominance with side of injury further differentiated deficits in shoulder strength and function in MARSOC personnel. Consistent with the hypothesis of the study, strength and functional asymmetries differed between those with a history of dominant and nondominant side injuries. Furthermore, strength deficits on the injured side were identified for those with a nondominant side injury compared to individuals with no history of shoulder injury.

Table 1. *Demographics.*

	CON (N = 195)	DOM (N = 26)	NONDOM (N = 26)	p Value (Effect Size)	Pairwise tests of significance
Age (years)	24.82 (3.69)	26.50 (4.56)	25.83 (4.42)	0.020*† (0.032)	DOM > CON
Height (cm)	178.96 ± 6.16	179.66 ± 4.16	180.18 ± 7.56	0.563 (0.004)	
Weight (kg)	81.91 (9.95)	84.82 (13.83)	82.55 (12.96)	0.117† (0.017)	
* Significantly different between groups ($p < .05$). † Indicates non-parametric data comparison; values expressed as median (interquartile range). For all others mean ± standard deviation is presented. CON, control group; DOM, dominant side injury group, NONDOM, nondominant side injury group.					

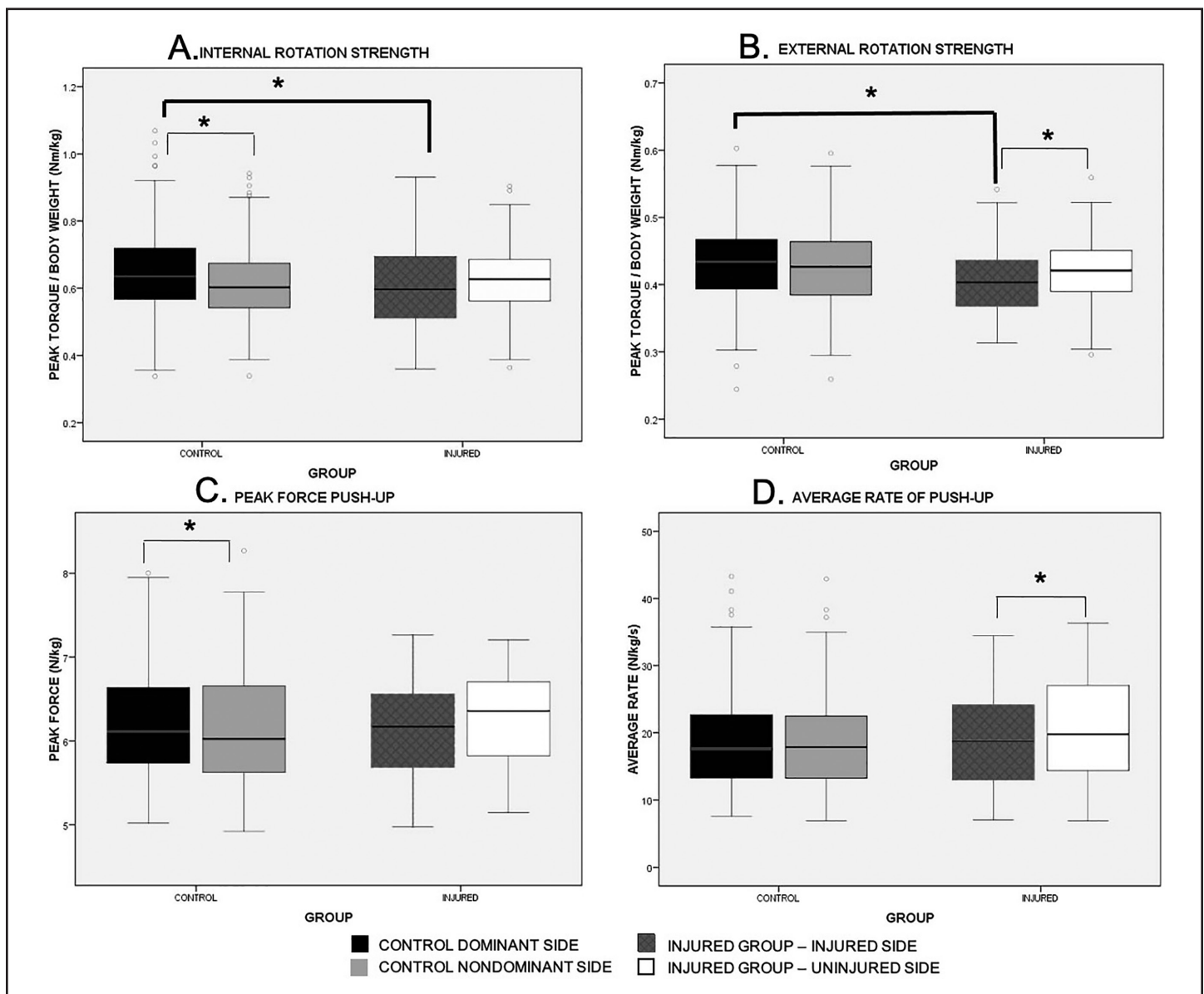


Figure 3. Boxplots of bilateral and INJ versus CON strength and push-up assessment comparisons. (A) Internal rotation strength comparison. (B) External rotation strength comparison. (C) Peak Force of push-up comparison. (D) Average rate of force production for push-up comparison. CON, control group; INJ, shoulder injury group. *Significant differences ($p < .05$) indicated.

These results support distinguishing side of injury based on limb dominance as unique asymmetry patterns were revealed. DOM demonstrated no significant asymmetries in strength or push-up performance. Conversely, NOND performed significantly worse on the injured/nondominant side in IR and ER strength as well as both explosive push-up performance measures. Initial review of the included assessments might suggest that DOM had fully recovered from injury as they demonstrated symmetrical strength and push-up performance;

however, this may be misleading as this pattern is different from that of CON, which demonstrated greater IR strength and Peak Force on the dominant side. In contrast, as NOND demonstrated significant deficits on all assessments on the injured side within group, they may appear to have greater deficits than DOM. However, as CON was not symmetrical, complete strength and functional symmetry may not be realistic or necessary in this population due to unique dominant versus nondominant upper extremity demands. These distinct patterns

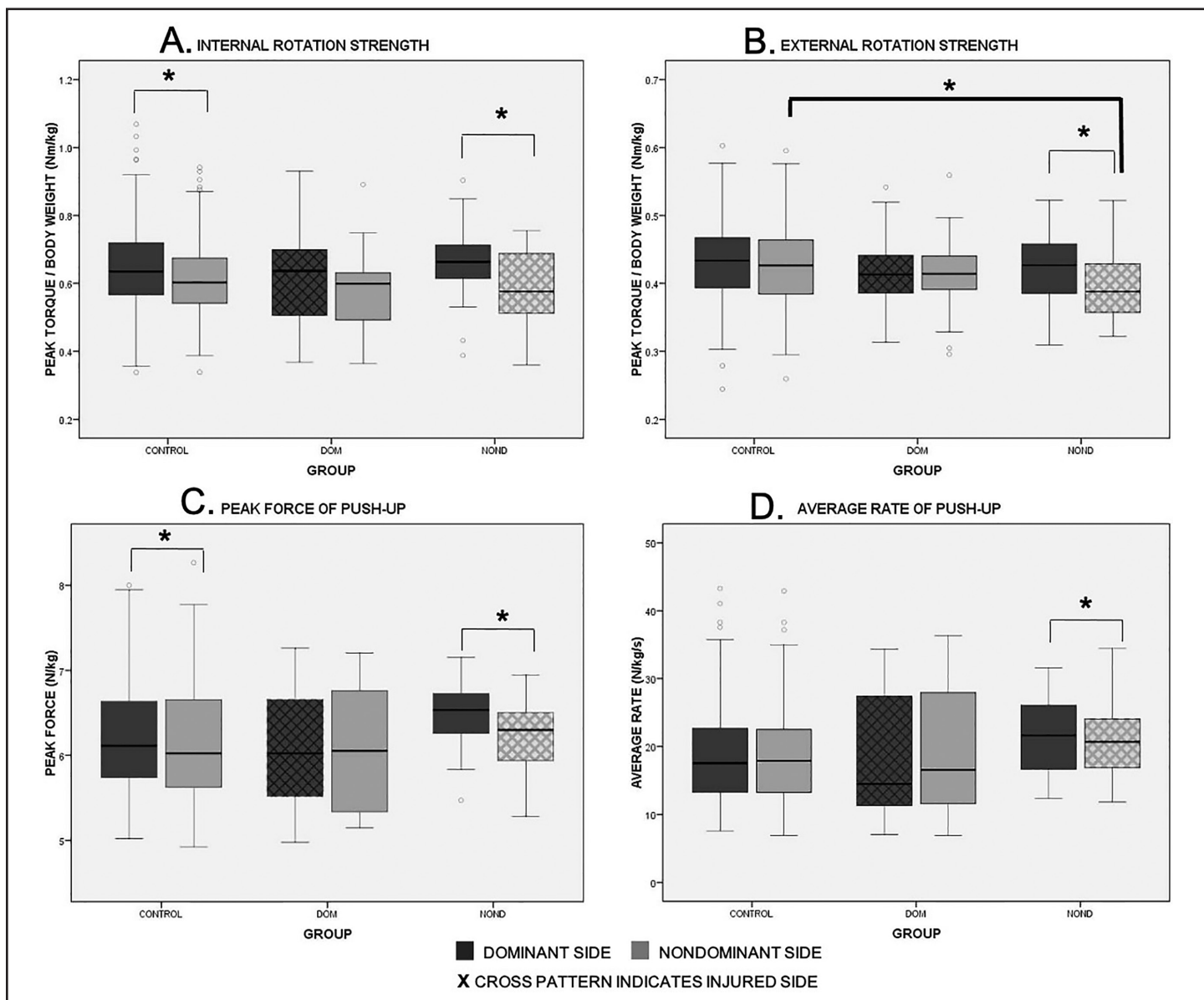


Figure 4. Boxplots of bilateral and between group (DOM, NOND, and CON) strength and push-up assessment comparisons. (A) Internal rotation strength comparison. (B) External rotation strength comparison. (C) Peak Force of push-up comparison. (D) Average rate of force production for push-up comparison. DOM, dominant side injury group, NOND, nondominant side injury group. *Significant differences ($p < .05$) indicated.

of decreased symmetry for NOND and increased for DOM are lost when all are considered as one injured group. Though different populations, the current results mirror those of a study by Edouard et al.³⁸ of patients with recurrent unilateral anterior shoulder instability. The authors concluded that in those with dominant side involvement, asymmetries decreased and for those with nondominant shoulder involvement, side-to-side differences increased.³⁸

While grouping all shoulder injuries together may mask within group asymmetries, this same grouping may amplify deficits in comparison to a healthy control group. The findings of IR and ER deficits for INJ compared to CON are consistent with residual shoulder deficits found in other SOF with a history of shoulder injury compared to healthy controls.^{1,21} These findings may be misleading as these are comparisons of both dominant/nondominant injured shoulders to only the dominant or right side

of individuals without a history of shoulder injury. When differentiating limb dominance in side of injury in this study, the only between group difference found was a 9.76% ER deficit in NOND compared to CON. This finding is particularly relevant to a military population, whose workload can vary substantially throughout training and deployment cycles.^{39,40} Møller et al.⁴¹ found that athletes with decreased ER strength were more prone to shoulder injuries at moderate (20-60%) increases in training load and even greater risk at high training load (>60%) increases compared to the previous four weeks of training.⁴¹ Considering the variable military training schedule and the nearly 10% deficit found in ER in NOND, full recovery of ER strength following injury should be prioritized.

Further deficits following shoulder injuries have been studied in other special operations military populations.^{1,21} Bilateral strength differences of greater than 10% were reported in a substantial portion of full-duty SOF personnel with history of shoulder injury.^{1,21} In Navy SEALs, between 20% and 22% of participants demonstrated a greater than 10% deficit on their injured side in IR and ER strength respectively compared to the uninjured side.¹ Despite a significant portion of the injured group having at least a 10% deficit, overall the injured groups were found to be symmetrical in IR and ER strength.^{1,21} Just as between group differences may be misleading without consideration of limb dominance, side-to-side comparisons must also be interpreted with caution when all injured personnel are grouped together. By differentiating those with dominant and nondominant side injuries in this study, distinct symmetry patterns and deficits were found. Nearly 54% of NOND demonstrated a greater than 10% deficit in IR strength on the injured side compared to the non-injured side, while only 17% of DOM demonstrated a 10% deficit on the injured side in bilateral comparison. Similarly, for ER strength, 27% of NOND demonstrated a greater than 10% strength deficit on the injured side compared to non-injured side, while only 13% of DOM demonstrated a 10% deficit on the injured side in bilateral comparison. Again, these findings support consideration of limb dominance in side of injury for bilateral comparison as well as the conclusion by Edouard et al. that asymmetries

are more prominent following a nondominant side injury involvement and reduced when the dominant side is involved.³⁸

In an ever-demanding environment, the balance between adequate recovery following injury and mission readiness must be carefully considered. Common clinical practice suggests that patients' strength and functional performance be nearly symmetrical, usually within 10% bilaterally prior to return to full activity.⁴² For upper extremity injuries, bilateral comparison needs to be understood relative to limb dominance and task. In the context of this study, MARSOC personnel reporting an injury to their dominant limb were found to be symmetrical in IR strength, while those reporting an injury to their nondominant limb demonstrated a 12.9% deficit in IR on the injured side, double the nondominant side deficit of 6.45% in personnel reporting no shoulder injury. Those with no history of shoulder injury and those that reported a dominant side shoulder injury were symmetrical in ER strength, while those that reported a nondominant side injury displayed a 9.76% deficit on the injured side. In those reporting a nondominant side injury, peak force on the explosive push-up was only 3.59% less on the injured side compared to uninjured side; however, this indicates over double the bilateral difference found in those with no history of shoulder injury of 1.48%. Though a patient may appear ready for full activity as he presents with symmetrical strength and performance, he may be at risk of reinjury if this does not accurately depict his prior level of function. In contrast, another patient may not be able to reach perfect side-to-side symmetry following a nondominant side injury if he heavily relies on his dominant side for performance tasks.

Although manual muscle testing is a common assessment for monitoring strength progression, minor impairments typically cannot be captured. Individuals who demonstrate bilateral normal shoulder strength (5/5) with manual muscle testing, may still show significant bilateral differences of 13-28% when tested via isokinetic dynamometry.⁴³ In high performing populations, sensitive and quantifiable assessments, such as hand-held dynamometry, submaximal or maximal strength testing and functional assessments should be considered

as appropriate. Though deficits may be subtle, over time, these differences may increase the risk of reinjury and/or injury to the opposite shoulder as many injuries may stem from small amplitude, repetitive, and cumulative overloading often required during physical activity or occupational tasks.⁴⁴ For military personnel, injuries and even minor compromises in performance may impact safety, career longevity, and long-term health. While this study is specific to MARSOC personnel, the findings suggest that limb dominance should be considered in rehabilitation for military personnel and are likely applicable across SOF communities. Daily physical demands, typical presentation in the given population, and prior level of function should all be weighed in the clinical decision-making process.

The current study does have some limitations. Injury diagnoses were not differentiated in the analysis. Certain pathologies may affect individual muscle groups and therefore performance, differently. Though injury severity likely differed between participants, all had stopped or modified training due to the injury for at least one full day within the last year and none were treated operatively. There were also similar distributions of acute and chronic injuries as well as diagnoses and medical encounters between DOM and NOND. Additionally, all injuries were self-reported which may be limited by participant recall. To improve accuracy, only participants with injuries that influenced pain and/or activity within the prior year were included. Furthermore, by capturing injuries through patient recall, the authors were able to record injuries that disrupted training but would not have been captured with a medical record review.

CONCLUSIONS

Military personnel demonstrate asymmetric strength patterns likely due to increased demand of the dominant shoulder.²⁸ MARSOC personnel with history of injury to the nondominant shoulder performed differently than those with a dominant side injury, presenting with both strength and push-up asymmetries. Common clinical practice and previous literature often compares injured and uninjured limbs or injured individuals to healthy controls, but further distinction of dominant or nondominant side may provide more accurate information needed

to develop targeted assessments and treatment strategies.^{1,45,46} Prioritization of ER strength symmetry and recognition of side of injury to further individualize rehabilitation may lead to improved patient outcomes and decreased risk of re-injury following a shoulder injury.

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Appendix 1. Bilateral and INJ versus CON Comparisons.

	CONTROL				INJURED				Dominant CON side vs INJ injured side
	N	Dominant UE	Nondominant UE	P value (Effect Size)	N	Injured UE	Uninjured UE	p value (Effect Size)	p value (Effect Size)
Shoulder Strength (Nm/kg)									
IR	195	0.65 ± 0.13 0.64 (0.15)	0.62 ± 0.12 0.60 (0.13)	<0.001*† (0.482)	50	0.60 ± 0.13 0.60 (0.19)	0.62 ± 0.12 0.63 (0.12)	0.159 (0.202)	0.023*† (0.146)
ER	195	0.43 ± 0.06 0.43 (0.08)	0.43 ± 0.06 0.43 (0.08)	0.137 (0.101)	50	0.40 ± 0.05 0.40 (0.07)	0.42 ± 0.06 0.42 (0.06)	0.012* (0.370)	0.003* (0.483)
Explosive Push-up									
Peak Force (N/kg)	87	6.20 ± 0.68 6.11 (0.90)	6.12 ± 0.68 6.02 (1.05)	0.037*† (0.224)	39	6.14 ± 0.57 6.16 (0.90)	6.24 ± 0.61 6.36 (0.91)	0.058† (0.304)	0.610 (0.019)
Average Rate of Force Production (N/kg/s)	87	18.75 ± 7.49 17.57 (9.54)	18.70 ± 7.10 17.89 (9.39)	0.899† (0.014)	38	19.52 ± 7.26 18.75 (11.17)	20.34 ± 7.43 19.81 (13.15)	0.024* (0.381)	0.489† (0.062)

CON, control group; INJ, injured group; IR, internal rotation; ER, external rotation

Values expressed as mean ± standard deviation with median (interquartile range) below as parametric and nonparametric comparisons used as appropriate.

* Significantly different comparison ($p < .05$).

† Indicates non-parametric data comparison.

Appendix 2. Bilateral and Between Group (CON, DOM, NOND) Comparisons.

	CONTROL				DOMINANT SIDE INJURED				NONDOMINANT SIDE INJURED				BETWEEN 3 GROUPS	
	N	Dominant UE	Nondominant UE	p value (Effect Size)	N	Dominant UE	Nondominant UE	p value (Effect Size)	N	Dominant UE	Nondominant UE	p value (Effect Size)	DOM p Value (Effect Size)	NONDOM p Value (Effect Size)
Shoulder Strength (Nm/kg)														
IR	195	0.65 ± 0.13 0.64 (0.15)	0.62 ± 0.12 0.60 (0.13)	<0.001*† (0.482)	24	0.62 ± 0.15 0.64 (0.20)	0.59 ± 0.12 0.60 (0.15)	0.146 (0.307)	26	0.66 ± 0.12 0.66 (0.11)	0.58 ± 0.11 0.58 ± 0.18	<0.001* (0.832)	0.440† (0.007)	0.445† (0.007)
ER	195	0.43 ± 0.06 0.43 (0.08)	0.43 ± 0.06 0.43 (0.08)	0.137 (0.107)	24	0.41 ± 0.06 0.41 (0.05)	0.41 ± 0.06 0.41 (0.05)	0.941 (-0.015)	26	0.42 ± 0.06 0.43 (0.08)	0.39 ± 0.05 0.39 (0.07)	0.003* (0.656)	0.354 (0.009)	0.022* (CON/NOND) (0.031)
Explosive Push-up														
Peak Force (N/kg)	87	6.20 ± 0.68 6.11 (0.90)	6.12 ± 0.68 6.02 (1.05)	0.037*† (0.224)	19	6.05 ± 0.68 6.02 (1.21)	6.06 ± 0.73 6.05 (1.48)	0.904† (-0.028)	20	6.47 ± 0.43 6.53 (0.49)	6.22 ± 0.45 6.30 (0.58)	0.001* (0.920)	0.118 (0.034)	0.578† (0.009)
Average Rate of Force Production (N/kg/s)	87	18.75 ± 7.49 17.57 (9.54)	18.70 ± 7.10 17.89 (9.39)	0.899† (0.014)	18	18.29 ± 9.01 14.49 (16.74)	18.83 ± 8.83 16.57 (16.45)	0.184† (-0.313)	20	21.70 ± 5.80 21.65 (9.90)	20.63 ± 5.22 20.70 (7.25)	0.047* (0.476)	0.066† (0.044)	0.276† (0.021)

CON, control group; DOM, dominant side injury group; NOND, nondominant side injury group; IR, internal rotation; ER, external rotation

Values expressed as mean ± standard deviation with median (interquartile range) below as parametric and nonparametric comparisons used as appropriate.

* Significantly different comparison ($p < .05$).

† Indicates non-parametric data comparison.