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Trauma Exposure and Functional Movement Characteristics of Male Tactical Athletes

Marcus K. Taylor, PhD*||; Lisa M. Hernández, MS, TSAC-F*†; Pinata H. Sessoms, PhD‡||; Colton Kawamura, BS§; John J. Fraser, DPT, PhD, PT||

*Biobehavioral Sciences Lab, ‡Physical and Cognitive Research Laboratory, ||Warfighter Performance Department, Naval Health Research Center, San Diego, CA; †Leidos, Inc, San Diego, CA; §Naval Postgraduate School, Monterey, CA

Context: Tactical athletes commonly experience high levels of physical stress, which may increase their risk of musculoskeletal injury. It is critical to understand psychological predictors of functional movement (FM), which may help prevent musculoskeletal injury in this population.

Objective: To determine the associations of combat and trauma exposure with FM characteristics of male tactical athletes. Secondary objectives were to explore confounding influences of age and physical injury history as well as the mediating role of bodily pain.

Design: Cross-sectional study.

Setting: Research laboratory.

Patients or Other Participants: Eighty-two healthy, male, active-duty US Navy Explosive Ordnance Disposal personnel (age = 34.0 ± 6.7 years).

Main Outcome Measure(s): Participants completed measures of combat exposure, trauma exposure, physical injury history, and bodily pain. We assessed FM characteristics (ie, Functional Movement Screen [FMS], Y-Balance Test), from which we derived a composite functional status (CFS) measure. Hypotheses were tested using correlational and multiple regression (causal-steps) models.

Results: In unadjusted models, trauma exposure was inversely associated with the FMS ($P = .005$) and CFS ($P = .009$) scores. In adjusted models, these relationships were robust to the confounding influences of age and physical injury history. Trauma exposure and bodily pain were substantive, independent predictors of FMS and CFS in causal-steps models (all P values $< .05$), implying additive rather than mediated effects ($R^2_{adj} = 0.18$–0.20). Combat exposure did not predict FM characteristics.

Conclusions: To our knowledge, this is the first evidence of the influence of trauma exposure on the FM characteristics of male tactical athletes, independent of age, physical injury, and bodily pain. This program of research may help to advance the prevention and treatment of musculoskeletal injuries in the tactical environment.

Key Words: military personnel, psychological processes, athletic performance

Key Points

- Greater trauma exposure was associated with lower scores for functional movement.
- The influence of trauma exposure on functional movement was neither confounded by physical injury nor mediated by bodily pain.
- These findings will inform algorithms that are designed to predict injury risk in military and other tactical athletes.
- Clinicians and researchers in sports medicine and orthopaedic settings should consider the individual's trauma history when performing preparticipation physical screening and assessment after injury.

Military members experience high levels of physical stress.[1,2] In a recent report,[1] for instance, researchers identified load carriage, sprinting under heavy load, and negotiating complex terrain as challenges routinely faced by military personnel. Other stressors commonly linked to military training and operations include negative energy balance, sleep deprivation, and environmental extremes.[3]

Chronic physical stress, in turn, increases the risk of musculoskeletal injury.[1,3] For example, load carriage was implicated in 1 in 5 injuries of the back and lower limbs in the military setting, with muscular stress identified as the mechanism of injury in more than half of these events.[3] In fact, single load-carriage events have been reported to result in a high incidence of lower extremity injuries in military personnel and recreational hikers alike.[3] Similarly, stress fractures are prevalent among military members, particularly in training environments.[4] To date, studies of stress fractures in athletes have included only small samples, which cannot be directly compared with a military population.[4] Military and tactical organizations typically use physical training to address these threats, which is a rational strategy in light of solid evidence linking fitness to decreased injury risk.[5] Paradoxically, physical training is also a profound source of injury in the military sector,[6] likely due to excessive training volumes and inadequate rest. Jones and Hauschild [6] identified physical injury as the leading cause of medical encounters across the US military services, half of which were caused by physical training, exercise, or sport participation. Clearly, we need to determine complementary factors in tactical athletes that decrease injury risk and are modifiable with training.

Functional movement (FM) characteristics are potentially modifiable[7,8] and may help to decrease injury risk in tactical athletes.[9] Some attention has been given to measures of fundamental movement patterns and dynamic balance as univariate predictors of injury in sport participants and tactical athletes with varied results.[10] In a multivariate paradigm, however, Lehr et al[11] reported that FM characteristics combined algorithmically with injury history and bodily pain to predict injury occurrence in collegiate athletes. Bodden et al[7] showed that fundamental movements improved as a result of an 8-week "corrective exercise program" in mixed martial arts athletes, whereas Stanek et al[8] achieved similar results with male firefighters.

Factors that have been routinely cited as influencing FM among sport participants and tactical athletes include age,[12] body composition, flexibility,[13] and previous injury.[14] Yet these are unlikely to be the sole determinants. In fact, psychological antecedents of physical performance[15] and injury risk[16] are increasingly being recognized in athletes. In one such study,[15] self-reported fear predicted hop-test performance and isometric leg strength in athletes returning to sport after anterior cruciate ligament reconstruction. Further, psychological distress has been linked to increased injury prevalence due to falls, sprains, and strains in adult populations, for which proposed mechanisms included impaired concentration, perceptual errors, and psychomotor dysfunction.[17] However, scientific work exploring psychological influences on FM or injury risk in military populations is lacking.[18] This is surprising, not only because of the ubiquity of psychologically salient events in the military but also because of the importance of injury resistance in this domain.[1] When synthesized, a knowledge gap between theoretical and practical importance is apparent. Specifically, a clear understanding of psychological predictors of FM may help to advance the prevention and treatment of musculoskeletal injury in the tactical environment.

Trauma exposure is a significant, psychologically relevant factor that shapes a tactical athlete's occupational and life history. Such trauma exposure could include surviving a natural disaster, childhood physical abuse, sexual abuse, or physical assault. These types of events may exacerbate acute stress responses,[19] predict cognitive impairment[20] and poor physical health,[21] and disrupt pain processing.[22] It is, therefore, conceivable that trauma exposure may influence FM characteristics in tactical athletes. However, it is also likely that older tactical athletes have sustained more trauma exposure and have poorer FM characteristics[12] than their younger counterparts. Furthermore, traumatic exposure may co-occur with physical injury,[23] which may also disrupt FM.[11] Finally, bodily pain is empirically linked to trauma exposure[22] and FM[24] and, hence, may function as a mediator. Altogether, a test of the association between trauma exposure and FM should (1) rule out or adjust for confounding influences of age and physical injury history and (2) explore mediated effects of bodily pain.

In this study, we evaluated associations of combat and trauma exposure with FM characteristics of male tactical athletes, namely US Navy Explosive Ordnance Disposal (EOD) personnel. Secondary purposes were to assess confounding influences of age and physical injury history and to explore mediated effects of bodily pain. We hypothesized that combat or trauma exposure (or both) would be associated with poorer FM in these men and that the associations would be robust to age and physical injury history. We further predicted that the link between trauma exposure and FM would be mediated by bodily pain.

METHODS

This was a cross-sectional, laboratory-based study in which the independent variables were combat and trauma exposure and the dependent variables were clinical indicators of FM performance. As part of a larger investigation of biobehavioral health in this population (ie, the Explosive Ordnance Disposal [EOD] Operational Health Surveillance System), 82 male active-duty US Navy EOD operators stationed in California participated in this study. The EOD personnel are highly trained, skilled warriors with expertise in explosives, diving, and parachuting. They render safe all types of explosives and specialize in complex, clandestine operations, routinely embedding within Special Operations units, including US Navy Sea, Air, and Land specialists and US Army Special Forces. All questionnaires, including those about combat and trauma exposure, were presented before (and away from) FM assessments. Detailed participant characteristics are shown in Table 1. All participants provided informed consent, and the research protocol (NHRC.2015.0013) was approved by the local institutional review board.

Combat exposure was measured using a 17-item scale adapted from previous measures.[25] The scale is used to assess combat experiences during participants' most recent deployment (eg, "I was wounded in combat" or "I took care of injured or dying people"). Response options ranged from 1 (*never*) to 5 (*51 times or more*). Participants reporting no combat deployments are assigned a 0 value on the scale, and the range of possible scores is 0 to 85.

The Brief Trauma Questionnaire[26] (BTQ) is used to assess a history of exposure to potentially traumatic events. It consists of 10 *yes-no* questions regarding exposure to various types of trauma (eg, natural disasters, childhood physical abuse, sexual abuse, muggings, assaults). Participants responding in the affirmative to any of the questions are then presented with 2 additional questions: "Did you fear for your life?" and "Were you seriously injured physically?" The BTQ yields a total number of types of trauma exposure and is considered a reliable, valid measure of trauma exposure that parallels clinical interviews of trauma exposure.[26] The range of possible scores is 0 to 10.

The Functional Movement Screen (FMS; Functional Movement Systems, Chatham, VA) involves a series of fundamental movements that require flexibility, mobility, and stability.[27,28] The FMS comprises 7 individual movement patterns: squat, hurdle step, forward lunge, shoulder mobility, active straight-leg raise, push-up, and rotary stability. An ordinal scale ranging from 0 to 3 is used to score each item: 0 (*pain with any part of the movement*), 1 (*inability to complete the movement as instructed*), 2 (*movement with some compensation but without pain*), or 3 (*correct movement without pain*). Total FMS scores range from 0 to 21. One of 3 raters, all of whom were cross-trained and blinded to combat and trauma exposure scores,

Table 1. Participant Characteristics

Characteristic	No. or n (%)	Mean ± SD	Range
Age, y	82	34.0 ± 6.7	22–49
Height, cm	82	179.4 ± 6.3	159.0–196.4
Weight, kg	82	89.5 ± 15.7	67.7–200.2
Pay grade			
Enlisted	53 (64.6)		
Officer	29 (35.4)		
Education			
High school graduate or equivalent	10 (11.0)		
Some college or associate degree	35 (42.7)		
College undergraduate degree or greater	37 (45.1)		
Race or ethnicity			
White	78 (95.1)		
Other	2 (2.4)		
Missing	2 (2.4)		
Trauma exposure	77	2.9 ± 2.0	0–9
Involving fear for life	2 (2.4)		
Involving physical injury	1 (1.2)		
Combat exposure	69	37.2 ± 12.7	17–72
Physical injury history			
0	17 (20.7)		
1	19 (23.2)		
2	24 (29.3)		
3	5 (6.1)		
4	6 (7.3)		
Missing	11 (13.4)		
Bodily pain (Numeric Pain Rating Scale)	70	2.3 ± 1.5	0–6
Pain medication use?			
Yes	30 (36.6)		
No	52 (63.4)		
Functional Movement Screen score	82	15.6 ± 2.3	8–21
Y-Balance Test			
Left composite score	82	98.4 ± 7.3	80.6–115.4
Right composite score	82	98.4 ± 7.8	78.9–114.0

conducted the FMS. The test has demonstrated good to excellent interrater reliability for novice and expert raters for all components.[29]

The Y-Balance Test (YBT; Functional Movement Systems) is a measure of dynamic balance based on the anterior, posteromedial, or posterolateral direction of the Star Excursion Balance Test.[30] The protocol requires each participant to maintain control in single-limb stance while reaching with the free lower limb in the anterior, posteromedial, or posterolateral direction before returning to the starting position. We measured the reach distance by reading the tape measure in centimeters at the near edge of the reach indicator, closest to the center of the instrument, at the point where the most distal part of the foot reached. Reach distance was normalized to lower limb length,[31] measured from the most inferior aspect of the anterior-superior iliac spine to the most distal aspect of the lateral malleolus. Participants performed 3 practice trials in each reach direction (with shoes off) to account for the learning effect of this dynamic-balance motor skill, after which the best score of 3 test trials was used for analysis. For each direction, participants performed 3 trials on the right and then repeated the protocol on the left. We calculated an overall performance score on the YBT by averaging the maximal normalized reach distance for the 3 directions; this generated the composite reach score. One of 3 cross-trained raters conducted the YBT. Excellent intrarater and interrater reliability scores have been reported for this measure.[32]

We normalized (z-transformed) and summed the scores from the FMS and YBT to yield a synthesized measure of functional status. We used this exploratory measure only in inferential hypothesis tests; it was not used descriptively, and no norms are available for this measure.

Candidate confounders for this study included age[12] and physical injury history.[11] Participants responded to the question, "Have you ever suffered an injury to any of the following parts of your body that required medical treatment, or that limited your ability to complete your daily activities?" Body parts listed were head/neck, upper extremities (ie, shoulder, arm, elbow, hand, wrist), lower extremities (ie, hip, leg, knee, ankle, foot), or trunk (ie, chest, back, abdomen, spine, pelvis). Self-reported injury data were reviewed and confirmed after a degreed exercise physiologist interviewed the participant. We synthesized the responses as a single measure of physical injury history, with scores ranging from 0 to 4, reflecting the total number of bodily areas in which injuries had been sustained.

A candidate mediator for this study was bodily pain. Participants completed the Numeric Pain Rating Scale (NPRS), a unidimensional measure of pain in adults.[33] Specifically, participants were asked to report their average bodily pain on a scale ranging from 0 (*no pain*) to 10 (*worst pain imaginable*). Construct validity and test-retest reliability in diverse populations have been shown for this instrument.[33] The NPRS also correlated highly with the Defense and Veterans Pain Rating Scale[34] in a subset of the current sample (n = 25, $r = 0.80$, $P < .001$). Because bodily pain may be influenced by the use of pain medication, we also asked participants to report whether they were taking medications for chronic pain.

Data were analyzed using SPSS (version 23.0; IBM Corp, Armonk, NY). We conducted descriptive analyses to summarize participant characteristics. To test each hypothesis, unadjusted associations between independent (combat and trauma exposure) and dependent (FMS score, YBT score, and composite functional status [CFS] score) variables were first evaluated with Pearson product moment correlational models. Next, we evaluated theoretically relevant confounders (eg, age and physical injury history) and the candidate mediator (ie, bodily pain) as potential covariates following standardized selection criteria. Specifically, a variable was selected as a covariate if it related to an independent (eg, trauma exposure) and a dependent (eg, FMS score; all P values $< .05$) variable, thus qualifying as a potential confounder or mediator.[35] A theoretically supported candidate mediator (bodily pain) was further scrutinized following the principles of the Baron and Kenny causal-steps approach.[36]

RESULTS

As shown in Table 1, most participants were enlisted men who had completed at least some college coursework. The

Table 2. **Unadjusted Associations Between Independent (Psychological Trauma Exposure and Combat Exposure) and Dependent (FMS, YBT, and CFS Scores) Variables**

	1. Psychological Trauma Exposure	2. Combat Exposure	3. FMS	4. YBT (Left)	5. YBT (Right)	6. CFS
1.	—	0.43[b]	−0.32[a]	ns	ns	−0.30[a]
2.		—	ns	ns	ns	ns
3.			—	0.37[b]	0.38[b]	0.80[b]
4.				—	0.88[b]	0.83[b]
5.					—	0.84[b]
6.						—

Abbreviations: CFS, Composite Functional Status; FMS, Functional Movement Screen; ns, not significant; YBT, Y-Balance Test.

[a] $P < .01$.

[b] $P < .001$.

average participant had been exposed to approximately 3 types of traumatic events, had substantial combat exposure, and registered FM and balance scores that, according to published studies,[7,8,10,12,14] were within normal ranges. Nearly 4 of 5 participants endorsed a history of physical injury affecting at least 1 area of the body (eg, trunk, lower extremity). Data from all participants were included in the analysis.

We report unadjusted associations between the independent (combat and trauma exposure) and dependent (FMS score, YBT score, and CFS score) variables in Table 2. Trauma exposure was inversely associated with FMS (r[75] = –0.32, P = .005) and CFS (r[75] = –0.30, P = .009) scores. Combat exposure did not predict any FM characteristics.

Age met the criteria for covariate selection in the relationships between trauma exposure and CFS but did not contribute to the adjusted (regression) model ($P > .05$). Physical injury history did not meet the criteria for covariate selection in the associations of trauma exposure with FMS and CFS scores, respectively. Bodily pain met the criteria as a candidate mediator[36] in the relationships of trauma exposure with FMS and CFS scores. We summarized the causal-steps models exploring the mediated effects of bodily pain with respect to FMS score in Table 3. In this model, both trauma exposure and bodily pain were substantive, independent predictors of FMS score (R^2_{adj} = 0.20), implying additive rather than mediated effects. A similar pattern prevailed with respect to CFS score (R^2_{adj} = 0.18). Because the participants who endorsed pain medication use (n = 26) also reported greater bodily pain (mean ± standard deviation [SD] = 3.3 ± 1.5) than nonusers (n = 44; mean ± SD = 1.8 ± 1.8; t_{68} = –5.0, $P < .001$), the 2 aforementioned causal-steps models were repeated to include pain medication use as an additional predictor of FMS and CFS scores. However, pain medication use did not affect either model (all P values > .05).

DISCUSSION

In this study, we discovered novel associations between trauma exposure and the FM characteristics of male tactical athletes, revealing 9% to 10% of shared variance in the unadjusted models. In the combined models, these relationships were robust to the confounding influences of age and physical injury history and were not mediated by bodily pain. A logical inference is that a history of trauma exposure negatively affected FM characteristics, which, in turn, placed a person at greater risk for musculoskeletal injury. These findings are potentially generalizable to virtually all athletic populations because trauma exposure and diminished FM characteristics are universal concerns.

Trauma exposure was inversely associated with FM characteristics in our participants, which demonstrates that the movement competency and dynamic balance of this population were diminished with increasing exposure to traumatic experiences or events. We anticipated this in light of research linking psychological factors to movement characteristics in sport athletes and trauma exposure to acute stress reactions,[19] physical health,[21] and pain.[22] As alluded to earlier, self-reported fear predicted physical performance in participants returning to sport after surgery,[15] and psychological distress was linked to injury prevalence in adult populations.[17] Our findings suggest that such mind-body connections may be extrapolated to FM characteristics in a military population. However, the observed associations were limited to a measure of trauma exposure across an individual's life, rather than a more focused measure of combat exposure. Although the average trauma score was low for this sample (2.9/10), roughly one quarter of the sample scored 5 or more on the trauma exposure scale. This may further indicate that traumatic events occurring outside of military service and events that an individual is not specifically trained to encounter in the occupational setting may have a greater effect on FM outcomes. Answers to more refined questions such as these await further research.

It is also important to establish the clinical and operational significance of these results. Approximately 10% of the shared variance was captured between trauma exposure and FM characteristics, and the relationships were robust to candidate confounders. This implies that substantial value was added not only by including trauma exposure and other psychologically relevant constructs (ie, fear, self-efficacy) in hypothesis tests to advance theories of FM but also in screening algorithms designed to predict injury risk in military and other tactical athletes. As described earlier, investigators have shown that FM characteristics combined algorithmically with injury history and bodily pain predict injury occurrence in collegiate athletes. Our findings suggest that including trauma exposure or similar con-

Table 3. **Combined Associations of Psychological Trauma Exposure and Bodily Pain With Functional Movement Screen Score**

Predictor	β	t	P Value
Psychological trauma	−0.29	−2.5	.02
Bodily pain	−0.29	−2.5	.02

structs may improve the predictive capabilities (ie, sensitivity and specificity) of similar models in tactical athletes.

We evaluated 2 potential confounders of the relationship between trauma exposure and FM characteristics of these tactical athletes. First, we anticipated that age could be a confounder in that older participants might report more trauma exposure while also performing more poorly than their younger counterparts on measures of FM. In this study, age met the criteria for covariate selection in the relationships of trauma exposure and CFS score but did not contribute to the adjusted model. Second, trauma exposure may co-occur with physical injury, which has been linked to FM. In the current study, trauma exposure was disentangled from physical injury in 2 ways. First, only 1 of the study participants ($n = 82$) endorsed a physical injury concomitant with a traumatic event. Second, our broader measure of physical injury history did not meet the criteria for covariate selection in the relationships of trauma exposure with FMS and CFS score. Barring potential measurement error (discussed in the next paragraph), we concluded that the observed associations between trauma exposure and FM in tactical athletes were robust to 2 candidate confounders.

Prompted by biologically plausible evidence linking bodily pain to trauma exposure and FM, we expected that associations between trauma exposure and FM characteristics would be explained (ie, mediated) by bodily pain. However, causal-steps modeling showed that trauma exposure and bodily pain were substantive, independent predictors of FM, implying additive rather than mediated effects. Combined, these variables explained substantial variance (18%–20%) in FM, and the observed standardized β weights revealed equivalent contributions. Accordingly, it appears that trauma exposure and bodily pain have the potential to not only advance theory but also improve injury screening algorithms, as previously discussed. However, underlying mechanisms explaining the trauma exposure–FM relationship must be identified. This is a focus of another study in which we aim to replicate the current results and evaluate the mediating roles of behavioral health,[37] self-efficacy, and physiological stress profiles.[38]

We recommend that clinicians and researchers in the sports medicine and orthopaedic settings consider assessing trauma history when performing preparticipation physical screening and evaluation after injury. The use of patient-reported outcome measures or structured interviews quantifying trauma exposure may not only help to contextualize the physical findings but also identify those who could benefit from a behavioral health referral. Furthermore, providing verbal encouragement, support, and reassurance during functional assessments may facilitate a greater effort by the patient and improved measurement accuracy during screening and evaluation.

We note some limitations of our study. First, many scientists and clinicians consider a clinical interview to be a the criterion standard measure of trauma exposure, but we evaluated this construct by questionnaire. That said, the questionnaire is considered a reliable and valid[26] measure of trauma exposure that parallels clinical interviews. Also, physical injury history relies on autobiographical memory and is, therefore, vulnerable to recall bias and memory degradation. Furthermore, time since injury, lost duty days, and injury severity were not queried. As with all self-reported measures, it is possible that a participant may withhold or provide inaccurate information. Additionally, although we measured FM with valid and reliable instrumentation, the extent to which these measures are sensitive and specific longitudinal indicators of physical injury occurrence is not entirely clear.

CONCLUSIONS

This study revealed novel associations between trauma exposure and the FM characteristics of male tactical athletes. To promote successful injury treatments and recoveries, clinicians might consider incorporating a metric of trauma exposure into patient intake assessments as well as treatment and rehabilitation plans. Such a multidisciplinary approach could optimize patient care and health outcomes.

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Address correspondence to Lisa M. Hernández, MS, TSAC-F, 140 Sylvester Road, San Diego, CA 92106. Address e-mail to lisa.m.hernandez75.ctr@mail.mil.