Musculoskeletal injuries in military personnel – descriptive epidemiology, risk factor identification, and prevention

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Abstract

Objectives: To provide an overall perspective on musculoskeletal injury (MSI) epidemiology, risk factors, and preventive strategies in military personnel.

Design: Narrative review.

Methods: The thematic session on MSIs in military personnel at the 5th International Congress on Soldiers' Physical Performance (ICSPP) included eight presentations on the descriptive epidemiology, risk factor identification, and prevention of MSIs in military personnel. Additional topics presented were bone anabolism, machine learning analysis, and the effects of non-steroidal anti-inflammatory drugs (NSAIDs) on MSIs. This narrative review focuses on the thematic session topics and includes identification of gaps in existing literature, as well as areas for future study.

Results: MSIs cause significant morbidity among military personnel. Physical training and occupational tasks are leading causes of MSI limited duty days (LDDs) for the U.S. Army. Recent studies have shown that MSIs are associated with the use of NSAIDs. Bone MSIs are very common in training; new imaging technology such as high resolution peripheral quantitative computed tomography allows visualization of bone microarchitecture and has been used to assess new bone formation during military training. Physical activity monitoring and machine learning have important applications in monitoring and informing evidence-based solutions to prevent MSIs.

Conclusions: Despite many years of research, MSIs continue to have a high incidence among military personnel. Areas for future research include quantifying exposure when determining MSI risk; understanding associations between health-related components of physical fitness and

MSI occurrence; and application of innovative imaging, physical activity monitoring and data analysis techniques for MSI prevention and return to duty.

Keywords: Military Personnel; Machine Learning; Public Health; Fractures, Stress

Introduction

Military personnel are exposed to intense physical demands in their training and operational environments,[1] which increases their risk of musculoskeletal injuries (MSIs).[2] MSIs cause morbidity,[3] disability,[4] and attrition in military populations,[5] and high financial cost to the military.[6] Overuse MSIs caused by cumulative microtrauma are an important component of MSIs in military personnel.[7, 8]

MSIs among U.S. Army soldiers often lead to limited duty days (LDDs),[9] which are defined as the number of days of restrictions to work or training issued to military members due to adverse health conditions causing physical or mental limitations. Military readiness depends on the ability to effectively perform military-oriented tasks, whenever and wherever needed, while remaining healthy and uninjured. This is achieved through training that develops requisite levels of physical fitness and competencies to perform required tasks, while also mitigating MSI risks.[1, 10] Documentation of MSI-associated LDDs has been incomplete in the medical records, while self-report surveys may be affected by recall bias.[11, 12] Until 2019, LDDs among U.S. Army soldiers were estimated using medical record reviews or self-report surveys as proxies. MSIs requiring LDDs are in some cases more severe than those solely requiring an office visit, without limitations to work or training, and have a greater effect on soldier readiness. The U.S. Army now uses an electronic profile system (eProfile) that allows medical providers to record LDDs, mechanism of injury, and return to duty times following MSIs, which provides more information than that contained in medical records. To effectively focus prevention efforts, information on mechanisms of MSIs is necessary.

One specific type of MSI, stress fractures, is a pervasive and costly problem in military personnel, impacting up to 20% of women and 6% of men undergoing initial military training.[13] In animal models, physical activity-induced bone formation was shown to greatly increase the fatigue resistance of bone.[14] It has been hypothesized that in humans, individual variation in exercise-induced bone formation may contribute to differences in stress fracture risk during times of increased physical activity, such as military training.[15] A recent study in the U.S. Army identified a 2.9-fold increased risk of diagnosed stress fractures among soldiers prescribed non-steroidal anti-inflammatory drugs (NSAIDs).[16] This finding led to an exploration of whether NSAIDs usage similarly increases MSI risk in other military personnel such as Israel Defense Force (IDF) soldiers. An overuse MSI, Medial Tibial Stress Syndrome (MTSS) has been identified as the most costly MSI in the British Army.[17] There is no reliable treatment for MTSS and reoccurrence rates are high.[18] Prevention of MTSS is critical to reducing its operational burden. Typically, MSI prediction is complex, has multiple contributing causes, and has not been capable of discerning individual level risks.[19] Machine learning approaches can combine best known risk factors into an individual risk profiling tool for MTSS.

Naval Special Warfare (NSW) Sea, Air, and Land (SEAL) and Special Warfare Combatant-craft Crewman (SWCC) Operators are a group of specialized military personnel trained to participate in unconventional warfare, and are especially susceptible to MSIs, likely due to their high physical and operational demands.[20] Paradoxically, the physical training (PT) that can result in MSIs is also required to improve performance in military personnel.[21] The same parameters of exercise (intensity, duration, and frequency) that determine the positive fitness and health effects of PT also appear to influence MSI risk.[22] Cutting-edge technologies including the use of physical activity monitors, data linkage from various sources (e.g., medical, physical fitness, activity), and machine learning algorithms can improve decision making in the management of overuse MSIs.

The purpose of this manuscript was to provide an overall perspective on each of the eight unique topics that were presented during the thematic session "Musculoskeletal injuries in military personnel – descriptive epidemiology, risk factor identification, and prevention" at the 5th International Congress on Soldiers' Physical Performance (ICSPP). The authors have summarized and evaluated important aspects of the existing literature, identified significant gaps, and outlined areas for future study. The focus of this narrative review was on each specific topic in the thematic session, instead of an extensive literature review. The narrative review of each of the eight topics is presented in this manuscript in the same order as they were presented during the thematic session at the 5th ICSPP.

Causes of Injury and Associated Days of Limited Duty among Soldiers in the U.S. Army

MSIs are a leading health problem for U.S. Army soldiers. In 2018, over 50% of U.S. Army soldiers sought medical care for any MSI, resulting in over two million medical encounters.[9] MSI-related LDDs represent significant costs to the Army due to lost training and work time.[23] From January through June 2019, over seven million LDDs were prescribed to over 122,000 soldiers who were assigned LDDs by Army medical providers, as recorded in the eProfile system (**Table 1**). Over half (4.1 million days, 59%) were due to MSIs, followed by 724,000 days (10%)

due to pregnancy-related conditions, and 709,000 days (9%) due to behavioral health disorders. Among MSIs, leading causes associated with LDDs were running (43%), work-related tasks (11%), falls (10%), road marching (8%), and sports (7%) (**Supplementary Table 1**). Results were consistent with prior investigations of activities associated with Army MSIs; running is commonly the leading activity associated with MSIs.[21, 24, 25]

Table 1: Leading medical conditions associated with limited duty days, active duty U.S. Army soldiers, January-June 2019

Supplementary Table 1: Leading mechanisms of injury associated with limited duty days for musculoskeletal conditions, active duty U.S. Army soldiers, January-June 2019

The amount and type of PT represents an important risk factor for MSIs. Civilian and military studies show that higher amounts of activity result in elevated MSI risk.[26] A study of male Army recruits during basic training found that MSI risk increased as footsteps per day increased. MSI risk for the highest activity group (17,948±550 steps/day) compared with the lowest activity group (14,722±400 steps/day), was 1.9 times greater for men (95% confidence interval (CI): 1.5-2.6) and 1.4 times greater for women (95% CI: 1.1-1.8).[27] In addition to amount of activity, type of activity is also important to consider when determining MSI risk, as certain military activities like road marching and obstacle courses have higher MSI risks per unit of exposure. For example, a 2017 study of an U.S. Army infantry unit demonstrated a 1.8 times greater risk of injury per mile due to road marching (95% CI: 1.4-2.4), compared with running.[25] However, since running is a more frequent activity, it contributes a greater number of LDDs

(**Supplementary Table 1**). In a study conducted during U.S. Army basic training, risk of MSI per hour of activity was 4.8 times greater during road marching (95% CI: 1.1-20.4), and 7.5 times greater during obstacle course events (95% CI: 1.8-30.6), compared with routine PT.[28]

Data presented by members of the U.S. Army Public Health Center (APHC) in this section are results from routine, systematic injury surveillance and operational studies that were reviewed and approved as public health practice by APHC's Public Health Review Board.

<u>Relationship of Musculoskeletal Injuries, Physical Fitness, and Military Performance in the U.S. Army</u>

The associations of health-related components of physical fitness (aerobic capacity, muscular strength, and endurance, body composition, and flexibility) with MSIs are well documented. Aerobic capacity has the strongest and most consistently reported negative association with MSIs.[29-31] Service members with lower aerobic capacity (e.g., slower 2-mile run time, lower VO_2max) have between 1.4 and 2.4 times higher MSI risk compared with those with higher aerobic capacity.[29, 30] For example, Knapik *et al*. found that men and women in the slowest quartile on a 3.2 km run at the start of basic training (men: ≥19.2 minutes; women: ≥23.5 minutes) had a 1.6 (95% CI: 1.0-2.4; p=0.04) and 1.9 (95% CI: 1.2-2.8; p<0.01) times higher risk of injury during training, respectively, compared with those in the fastest quartile (men: ≤15.4 minutes; women: ≤19.5 minutes).(30) When the combined effects of aerobic capacity and body mass index (BMI) were evaluated, individuals with the highest aerobic capacity and mid-to-high levels (quintiles) of BMI experienced the lowest MSI risk while those with the lowest BMI across all levels of aerobic capacity had the highest MSI risk.[32]

The requisite levels and combinations of health- and skill-related (e.g., speed, agility, balance, coordination) physical fitness vary by military task, but have not been defined for most tasks.[33] Yet, studies have consistently shown that service members with lower physical fitness (e.g., lower aerobic capacity) have higher risk of MSI compared to more fit individuals performing the same military training.[1, 10, 28] It is important that service members engage in appropriate types and intensity of physical and military training that will enable them to perform required tasks, while concomitantly minimizing injury risks. Future studies are needed to quantify the volume of physical and task-related training that units conduct and determine how MSI risks change at different activity thresholds. Additionally, more information is needed on the physical demand requirements of military tasks, and the fitness components necessary to train and perform military tasks in operational settings.

Musculoskeletal Injuries Receiving Lost Duty Days in the U.S. Army from 2017-2018

Data on MSI-associated LDDs are incomplete in medical charts, and self-report surveys suffer from issues with recall bias. The U.S. Army's eProfile system requires medical providers to record LDDs, injured body region, and activities associated with injury, whereas the medical records do not require this information to be documented. In 2017 and 2018, 21% and 24%, respectively, of active duty soldiers suffered a duty limiting MSI (with rates of 29 and 34 MSIs per 100 soldier-years, respectively). In 2017, the most injured body region was the knee (22%;

mean of 53 LDDs per knee injury), and the most common activities associated with knee MSIs were running, team sports, and fall/trip. The ankle/foot accounted for 20% of LDDs with the same three main activities associated with MSIs. The lumbar spine was the third most injured body region (15%), and the activities associated with these MSIs were running, occupational lifting, and PT, thus demonstrating that the activities associated with lumbar spine MSIs were slightly different than those associated with lower extremity MSIs. Additionally, although MSIs involving the knee were most frequent, MSIs involving the shoulder had the highest average LDDs. These patterns of MSIs were very similar in 2018. Rates for all MSIs calculated by either using medical encounters or surveys can be up to three times higher than rates for MSIs that resulted in LDDs, as not all MSIs result in LDDs. Three studies reported incidence rates of all MSIs from 95 to 156 MSIs per 100 soldier-years, much higher than the 29 and 34 LDD MSIs per 100 soldier-years for MSIs resulting in LDDs.[34-36]

Sex Differences in Bone Anabolism in U.S. Army Soldiers is Partially Explained by Baseline Bone Microarchitecture during Basic Combat Training

Bone MSIs, including stress fractures, occur frequently in military personnel.[23] Advances in non-invasive imaging technology, in particular, high resolution peripheral quantitative computed tomography (HRpQCT), has allowed in vivo, three-dimensional capture of bone microarchitecture.[37] The assessment of bone microstructure can be used to evaluate indices of mechanical bone strength, which is not possible when evaluating bone mineral content or density with dual x-ray absorptiometry techniques. This technology can be invaluable for increasing our understanding of the densitometric and structural underpinnings of stress fracture risk in susceptible individuals.[38] In the laboratory at the U.S. Army Research Institute of Environmental Medicine (ARIEM), by leveraging these improvements in technology, approximately 2% increase in total volumetric bone mineral density, trabecular volumetric bone density and in the trabecular bone volume fraction has been demonstrated to occur in female soldiers during eight weeks of basic combat training (BCT), and starting bone density was inversely related to bone changes during BCT.[39] Rat models have demonstrated that an increase as small as 2% in volumetric bone mineral density, can result in greater than 100 fold increase in the fatigue resistance of the loaded bone.[14] Thus, it has been postulated that the promotion of bone anabolism during times of heightened physical activity may be protective against stress fractures by increasing bone stiffness.[15]

Given the differing incidence of stress fracture by sex during BCT,[23] research has focused on the sex differences in bone formation. In unpublished findings, while female trainees seem to gain more trabecular bone during training, this difference is only partially explained by the fact that women on average have lower volumetric bone mineral density at the beginning of BCT. While lower bone density at baseline can partially explain the increased risk of stress fracture in women, this observation suggests there are potentially other modifying factors of new bone formation during BCT related to sex that may help to reduce the gap in injury risk between male and female recruits. As part of a large prospective cohort study called the ARIEM Reduction in Musculoskeletal Injury Study, the HRpQCT is being used to evaluate how a number of factors including demographics, life history, nutrition, sleep habits, and body composition influence changes in different bone parameters and stress fracture risk during a trainee’s time in BCT.[40]

Descriptive Epidemiology of Musculoskeletal Injuries among Naval Special Warfare Personnel

NSW Operators are especially susceptible to MSIs due to high physical training and operational demands.[20, 41] Peterson *et al.* described MSIs among NSW SEAL Operators and support personnel at a NSW Command location.[41] The MSI rate was reported as a range (0.9 to 3.2 injuries/100 person-months). The back/neck was the leading anatomic site for MSIs treated at the medical clinic (26.5% of visits), followed by the knee (20.9%). The most common MSI diagnosis was shoulder bursitis/impingement (9.3%), followed by lumbar strain/sprain (8.9%).[41] The Naval Health Research Center conducted a self-reported injury survey among SWCC Operators from three Special Boat Units to determine the prevalence of injuries.[42] A high percentage (64.9%) of SWCC Operators reported at least one MSI. The time period covered by this self-reported survey was not listed in the manuscript, and incidence was not calculated. The most prevalent MSI was strains/sprains (49.3%), and the most prevalent anatomic location was the lower back (33.6%).[42] A review of paper medical charts at two NSW installations demonstrated that the one-year cumulative incidence of MSIs was slightly higher among SWCC Operators (22 injured/100 Operators/year) compared with SEAL Operators (19 injured/100 Operators/year), though this difference was not statistically significant.[43] The most common anatomic location varied by NSW group – shoulder (21.6% of MSIs) among SEAL, and lumbo-pelvic spine (21.7%) among SWCC Operators. Data documenting cause of MSI were missing for a large proportion of MSIs in the medical charts. For MSIs with an identified cause of injury in the medical chart, the most frequent cause was lifting in both Operator groups (SEAL: 13.5%, SWCC: 16.7%).[43] There is no published research on the prevention of MSIs among NSW Operators. Many of these previous descriptive epidemiologic studies among NSW Operators utilized different methods of classifying MSI causes and anatomic locations, making comparisons between studies difficult. Also, MSI data are absent or incomplete if medical care is not sought, which is a known issue among military personnel.[44]

Physical Activity Monitoring to Quantify Training Load and Inform Injury Prevention Strategies

In athletic populations, relationships have been shown between physical activity exposure (described as training load) and MSI incidence and it has been proposed that training load needs to be balanced to minimize MSI risk whilst maintaining physical performance.[45, 46] In the military setting, the micro-traumatic forces and the MSIs they cause can result from a range of physical activities including exercise, recreation, sports, and occupational tasks.[47] Monitoring this physical activity to quantify parameters such as energy expenditure, activity patterns, and ground reaction forces using wearable technologies could provide an effective approach to predict impending MSI, and inform interventions to reduce MSI incidence.[48] However, to our knowledge no research has demonstrated the effectiveness of prospective monitoring of these parameters to inform interventions to reduce MSI in military settings. Training load can be quantified using a range of monitoring tools such as accelerometers, heart rate monitors, questionnaires, and global positioning system.[49] In the military setting, it is important to monitor all daily physical activity (not just pre-planned PT and exercise) and the selection of monitoring tools used needs to balance the participant burden, financial cost of devices, and the fidelity of the data required. These data should also be collated and presented in a format that is actionable by commanders, medical practitioners, physical trainers, and/or researchers.

Figure 1 presents a theoretical model that summarizes the relationship between physical activity, workload and moderators, and their impact on outcomes in military settings. A soldier's physical activity (both occupational, driven by their role, and leisure time) can be quantified in terms of frequency, intensity, time, and type (FITT), and in military settings should include quantifying external loads carried. These parameters collectively describe the external workload experienced by a soldier. For a group, the external workload may be the same (e.g. soldiers walking at a fixed pace carrying a load). However, the physiological response of each individual in the group will be different depending on a series of moderators which can either be modifiable (e.g. nutrition, hydration, fitness, sleep) or non-modifiable (e.g. previous injury, job requirements, environment, stature). The resultant outcome is described as the internal workload.

Figure 1: A model describing the relationship between physical activity, workload and moderators and their impact on outcomes in military settings

<u>A Machine Learning Algorithm to enhance decision making in the management of Medial Tibial Stress Syndrome</u>

Machine learning approaches have utility as individual risk profiling tools for overuse MSIs such as MTSS. An analysis of 10 risk factors, the first eight of which were identified in two previous systematic reviews,[50, 51] identified – lower years of running experience, a previous MTSS diagnosis, increased BMI, increased Navicular Drop, prior orthotic use, female sex, increased ankle plantarflexion range, increased hip external rotation range, increased running distance per session, and more running sessions per week as risk factors for prospective MTSS development.

Modelling including all these risk factors was used to determine the predictive accuracy of an ensemble of machine learners. Data was obtained from 123 recruits (28 females and 95 males) from a previous study.[52] Follow-up was conducted at three months to determine those in the group that had developed MTSS. Four ensemble learning algorithms- logistic regression (LR), k-nearest neighbors (kNN), Naïve Bayes (NB), and Decision Tree (Tree) were deployed and trained five times on random stratified samples of 75% of the dataset. The resultant algorithms were tested on the remaining 25% of the dataset and the models were compared for classification accuracy, precision and recall. Ranked classification accuracy for the various machine learning algorithms was (Tree= 0.987, NB=0.897, LR=0.800, kNN=0.755). Tree models improved predictive accuracy by 14.6% compared with a previously published multivariate model.[52]

Accurate identification of individuals at risk of MTSS is an important advance in the management of this difficult and costly problem. The ability to mitigate occupational risk is increasingly a responsibility of commanders and trainers. MSIs are often complex and multifactorial, making prediction and management arduous. Machine learning methodologies can provide decision makers with better tools for MSI control.

<u>Musculoskeletal injury rates among NSAID users in the IDF: a decades perspective</u>

The effect of NSAIDs on bone remodeling has been observed in animal studies, but is not very clear in humans.[53] NSAIDs act by inhibition of the cyclooxygenase enzymes, leading to suppression of prostaglandin production.[54, 55] Prostaglandins of the E series stimulate osteoblastic bone formation and inhibit the activity of isolated osteoclasts, which might lead to increased occurrence of MSIs among physically active individuals who use NSAIDs, such as athletes and military personnel.[56, 57]

Data in medical registries from soldiers that served in the IDF between the years 2009-2018, were reviewed to analyze non-pain related indications in medical encounters resulting in NSAIDs prescription. Non-pain related indications for prescriptions of NSAIDs included in the analysis, were indications where NSAIDs were prescribed for reasons other than musculoskeletal pain. Overuse MSIs that occurred after NSAIDs prescription were identified; acute/accidental injuries were not included in the analysis. The results of the prevalence of MSIs after NSAIDs or other treatment are presented in **Table 2**. There was an association between NSAID prescriptions and MSI as reflected in a significantly higher prevalence of diagnosed MSIs among soldiers prescribed NSAIDs coupled with a higher risk (1.3-2.3-fold) of developing MSIs during military service, independent of sex and/or service type. Future analyses of this topic should focus on duration of NSAIDs use, the exact phase in military training before MSI diagnosis, and the type and severity of MSIs as an outcome of NSAIDs use. Other medications used concomitantly also need to be assessed. For soldiers, particularly in combat training, maintenance of optimal health and performance, and prevention of MSIs is crucial to mission readiness.

Table 2: Prevalence (%) of musculoskeletal injuries after non-steroidal anti-inflammatory drug use or without it among soldiers who did not suffer from any musculoskeletal injuries prior to treatment

Conclusion

Despite many years of research on MSIs, they continue to occur frequently among military personnel. The purpose of this manuscript was to provide a narrative review on each of the eight subject areas or topics that were presented during the thematic session on MSIs in military personnel at the 5th ICSPP.

While running is a leading cause of MSIs for U.S. Active Duty Army personnel, time spent conducting the activity must be considered. Higher rates of MSIs per unit of exposure have been observed for military training events such as road marching and obstacle courses, but since running is a more frequent activity, it contributes a greater number of MSIs. Reporting MSIs with higher LDDs may provide more accurate results related to the effect of MSIs on readiness. Focusing prevention efforts on MSIs that result in the longest LDDs (i.e., to the knee, ankle/foot, lumbar spine, and shoulder) is recommended. While striving for medical and operational readiness, leaders should be aware of the inter-relationships of physical fitness, military task performance, and MSI risk. Among NSW Operators, MSI affecting the shoulder and lower back are most frequent. Future research should focus on further evaluating the etiology and prevention of MSIs among specific NSW Operator groups.

Understanding the factors that modify how bone adapts to PT, may be key in providing recommendations for countermeasures to reduce risk of stress fracture. Future analyses of MSIs should focus on duration of NSAIDs use and the exact phase in military training before MSI onset. Newer data analysis methods, including machine learning, hold promise to further improve identification and understanding of the cause of MSIs. Further research must determine the generalizability of these findings. The balance between the external and internal workload will impact an individual's physical performance and injury incidence. These combined individual outcomes all contribute to the organization's operational effectiveness.

Practical implications

- The incidence of musculoskeletal injuries is high in military personnel, and appropriate recording will allow leaders to best position medical providers for prompt treatment of these injuries, as well as help focus prevention efforts on musculoskeletal injuries that result in high limited duty days.

- Musculoskeletal injuries resulting in limited duty days reflect soldier readiness, whereas musculoskeletal injuries resulting in medical encounters reflect health care utilization. Both measures offer valuable insights.

- Road marching and obstacle courses have higher risks of injury per unit of exposure, as compared with routine physical training. Consider this when planning physical training schedules.

- Aerobic capacity and body mass index have an interactive effect on the risk of musculoskeletal injuries. Higher aerobic capacity is associated with the lowest injury risk. When the combined effects of aerobic capacity and body mass index were evaluated, individuals with the lowest body mass index across all levels of aerobic capacity had the highest injury risk.

- New imaging technology, physical activity monitoring, and machine learning could have important applications in monitoring and prevention of injuries.

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Figure 1: A model describing the relationship between physical activity, workload and moderators and their impact on outcomes in military settings

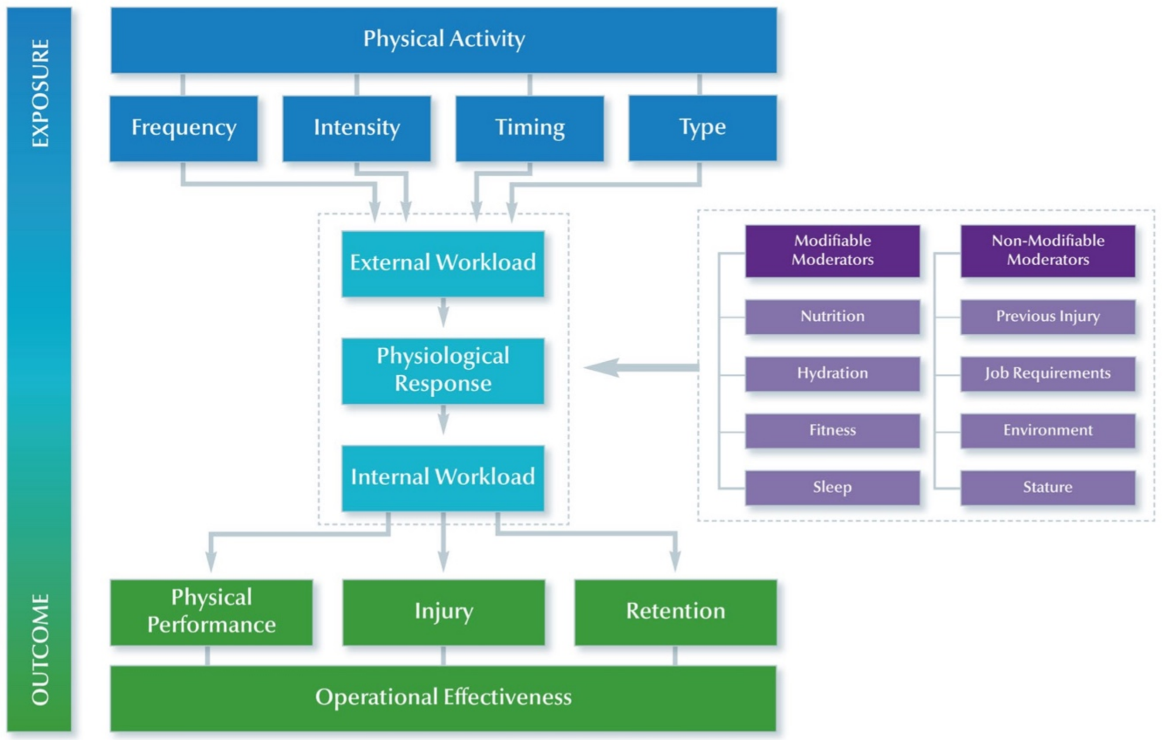

Table 1: Leading medical conditions associated with limited duty days, active duty U.S. Army soldiers, January-June 2019

	Men # of days (%)	**Women** # of days (%)	**Total** # of days (%)
Musculoskeletal Injury	3,298,697 (65.3)	857,717 (41.9)	4,156,414 (58.6)
Pregnancy/Post-partum	-	724,022 (35.4)	724,022 (10.2)
Behavioral Health	551,236 (10.9)	157,886 (7.7)	709,122 (10.0)
Neurology	111,507 (2.2)	30,475 (1.5)	141,982 (2.0)
General Surgery	81,689 (1.6)	23,716 (1.2)	105,405 (1.5)
All Other	1,007,181 (19.9)	250,900 (12.3)	1,258,081 (17.7)
TOTAL	5,050,310 (100)	2,044,716 (100)	7,095,026 (100)

Data source: eProfile from the U.S. Army Medical Operational Data System (MODS)

Notes: All soldiers with profiles=122,671; soldiers can be counted in more than one condition type. Profiles had start date between 01 January and 30 June 2019 and expiration date on or after 01 January 2019.

Table 2: Prevalence (%) of musculoskeletal injuries (MSIs) among soldiers with and without prior use of non-steroidal anti-inflammatory drugs (NSAIDs)

		NSAIDs treatment before MSI	No NSAIDs treatment before MSI	$X^2(1)$	Odds ratio	CI (95%)
Males	Combat	35.2%	27.5%	90.03*	1.43	1.33-1.54
	Non-combat	30.2%	21.7%	82.18*	1.56	1.41-1.72
Females	Combat	40.3%	26.9%	27.56*	1.84	1.45-2.33
	Non-combat	28.5%	19.4%	151.60*	1.65	1.52-1.79

*p<0.001

Supplementary Table 1: Leading mechanisms of injury associated with limited duty days for musculoskeletal conditions, active duty U.S. Army soldiers, January-June 2019

	Men n (%)	**Women** n (%)	**All** n (%)
Running	41,885 (41.0)	13,671 (50.6)	55,556 (43.0)
Occupational work tasks	11,882 (11.6)	2,465 (9.1)	14,347 (11.1)
Fall / slip / trip	9,919 (9.7)	2,445 (9.0)	12,364 (9.6)
Road marching / load carriage	6,975 (6.8)	2,705 (10.0)	9,680 (7.5)
Sports, individual or team	8,245 (8.1)	901 (3.3)	9,146 (7.1)
Strength training	6,792 (6.6)	1,311 (4.8)	8,103 (6.3)
Physical training, other	6,314 (6.2)	1,762 (6.5)	8,076 (6.2)
Motor vehicle / motorcycle accident	3,441 (3.4)	887 (3.3)	4,328 (3.3)
Fast rope, parachute	3,110 (3.0)	300 (1.1)	3,410 (2.6)
Combatives / martial arts / fighting	1,782 (1.7)	239 (0.9)	2,021 (1.6)
Off duty activities, non-vehicular	1,563 (1.5)	329 (1.2)	1,892 (1.5)
Battle injury	267 (0.3)	19 (0.1)	286 (0.2)
Environment, heat or cold	36 (0.04)	7 (0.03)	43 (0.03)
TOTAL	102,211 (100)	27,041 (100)	129,252 (100)

Data source: eProfile from the U.S. Army Medical Operational Data System (MODS)

Notes: Profiles had start date between 01 January and 30 June 2019 and expiration date on or after 01 January 2019. Injuries without a known cause are not included. Occupational work tasks includes Work tasks, other; Lifting, pushing, pulling; Mechanical/repair.