PHYSICAL TRAINING RISK FACTORS FOR MUSCULOSKELETAL INJURY IN FEMALE SOLDIERS

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ABSTRACT

Musculoskeletal injuries result in the most medical encounters, lost duty days, and service members on permanent disability. Women are at greater risk of injury than men and physical training is the leading cause of injury. The purpose of this study is to investigate the demographic, body composition, fitness, and physical training risk factors for injuries in female soldiers serving in operational Army units over the past 12 months. Self-report survey was collected from 625 women. Correlation, chi squared, relative risk, and logistic regression were used to analyze the results. The ankle was the most frequently injured body region, 13%. Running was the activity most often associated with injury, 34%. In univariate analysis rank, age, history of deployment, weekly frequency of unit runs, weekly frequency of personal strength training, and history of injury were all associated with injury. Having the rank of private to specialist increased the relative risk (RR) of injury by 68%, being in the Blue Brigade increased the RR by 48%, having no history of deployment increased the RR by 48%, having a history of injury in the last 12 months increase the RR by 160%, having no weekly unit runs increased the RR by 53%, having a weekly frequency of 1-2 personal weight training sessions increased RR by 42%, having a run time between 17 and 18 minutes increased RR by 71%, and having an Army Physical Fitness Score below 290 increased RR at least 70%. In multivariate analysis rank, history of injury, weekly frequency of unit runs, and weekly frequency of personal strength training were the best combination of predictors of injury in female soldiers. Running

once or twice a week with the unit protected against MSI while participating in personal strength training sessions once or twice a week increased the risk of MSI. Fitness was neither protective nor harmful when all other variables were accounted for in the equation. The public health significance is that with a higher emphasis on running and strength training, the US Army could reduce injuries and save billions of dollars in training and healthcare costs.

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1.0 INTRODUCTION

Musculoskeletal injuries (MSI) are a large problem in the US military. In 2011, more service members suffered musculoskeletal injuries (n=592,028) than any other health issue.[1] In addition, MSI accounted for more than one-fifth (21.1%) of all medical encounters.[1] They resulted in 2.5 times the number of patient visits compared to the next leading cause of visit, mental disorders.[2] The most common body regions injured in the US military are back/abdomen, ankle/foot, knee, and shoulder.[3] MSI often result in reduced unit morale and impaired ability to accomplish missions.[4]

MSI caused the greatest reduction in combat readiness compared to all other health problems, mental or physical.[5] A conservative estimate in 2006 stated that musculoskeletal injuries result in 25,000,000 limited duty days per year.[6] The average MSI can cause up to 18 days of limited duty, ten times the number of limited duty days due to illness.[7-10] Up to 60% of soldiers suffering injuries in the US were unable to return to full duty immediately, 10% while deployed to Iraq, and 20% while deployed to Bosnia and Afghanistan.[9,11-13]

The burden created by limited duty can be seen in decreased productivity. Service members who are replaced by other personnel for long periods of time will likely be sent to a medical review board and discharged from the military. Medical discharge rates from the military have increased over 600% in the last 20 years.[14] Medical discharges due to MSI have increased over 900% in men and over 1500% in women over the last 20 years and combined currently account for 78% of the medical discharges.[14] Twenty-nine billion dollars were spent on medical discharge payments in 2005 alone.[14] MSI are clearly a very large problem in the US Military resulting in high medical and disability costs as well as lost manpower.

1.1 MUSCULOSKELETAL INJURIES

Musculoskeletal injury is a broad and very inclusive category. It can include injuries to multiple anatomical regions as opposed to focusing solely on one area such as the low back. Additionally, MSI can include injuries from different causes such as motor vehicle crashes and excessive running. In most studies MSI were formally defined as injuries to muscle, bone, joint, or nerves.[15] This definition would still include a wide range of causes, diagnoses, and anatomical regions affected.

1.1.1 Musculoskeletal Injuries in the Military

A review of the MSI literature finds that various definitions of MSI have been applied. In some military studies, the definition of MSI included those seeking medical care, while in other studies the definition included seeking medical care and receiving a restriction to duty issued by the healthcare provider (lost duty days). Some military studies include injuries that may not be considered MSI by most medical providers such as blisters or concussions while others do not

(Table 1). The most commonly used definition is MSI requiring medical care and resulting in lost duty days (Table 1).

There are two main types of MSI, acute and overuse injuries.[15] Acute injuries occur all of a sudden, such as an ankle sprain, whereas overuse injuries occur through repetitive stress over time such as tendonitis. In 2006, 16% of the injuries across all four branches of the military were acute injuries: sprains, dislocations, and joint derangements.[16] Sprains accounted for 31% of the injuries seen in Air Force Cadet Training (training for six weeks the summer before freshman year at the Air Force Academy).[17] Ankle sprains were one of the top injuries in training and while deployed (stationed in a combat zone).[13,15] In patients seen by a deployed physical therapist, 12% were ankle sprains, the second most common diagnosis. The next most common acute injury was meniscal tears and accounted for only 3% of injuries and was the sixth most common injury.[13] Out of the 15 most common diagnoses seen by the deployed physical therapist, only four were acute injuries accounting for less than 30% of injuries.[13] While these acute injuries are less common than overuse injuries they are still important MSI.

Many musculoskeletal injuries are not acute injuries such as an ankle sprain or an anterior cruciate ligament tear but occur gradually overtime with repetitive stress. Performing the same activity for physical training at too high a frequency without enough rest could cause overuse injuries. Physical training (PT) is done every morning in the Army and Marine Corps and in some units of the Navy and Air Force. It is a mandatory, group run conditioning program that differs from small group to small group. PT can cause overuse which was reported to lead to 82% of injuries in the military according to one study.[16] A separate study found that 75% of injuries in Basic Training (nine week initial training of enlisted Army members, as opposed to officers) were due to overuse.[18] While overuse injuries are a major problem in both men and women, they are slightly more prevalent in women. Overuse injuries accounted for 70% of injuries in women and 65% in men at Marine Corps Officer Candidate School (six weeks of training for new officers).[19] Twenty-nine percent of male and 47% of female Army mechanics suffered an overuse injury over a one year period.[20] These injuries negatively impact the military because they result in lost duty days. In fact, overuse injuries led to the most lost duty days in Army mechanics.[20] They can lead to an average of 14-22 days of limited duty per injury.[10] They are more prevalent in women and result in more lost duty days; 64% of the male lost duty days and 83% of the female lost duty days in Marine Corps Officer Candidate School.[19]

1.1.2 Injury Capture Methods

The different case definitions used by different studies also result in different levels of injury capture. Injuries are typically recorded by three methods: electronically, medical record review, or self-report.[21-24] Over the last decade the military has gradually switched to electronic medical records. Initially, only hospital visits were recorded electronically. This expanded to include large clinics and gradually Aid Stations (very small clinics). This transition is still not complete; some Aid Stations still do not have electronic capabilities. Some deployed clinics do not have electronic capabilities and even in those that do, not all electronic notes upload to the soldier's record. In studies performed in garrison, if Aid Stations are excluded and self-report was not used, the number of injuries captured was much lower, in fact the two studies excluding Aid Station visits had the lowest percentage of injury of all the studies (Table 1). In these two studies the authors could have used self-report or medical records review to capture the Aid Station visits. In deployed settings even medical record review is not accurate as soldiers may be seen at different clinics in order to see specialists such as physical therapists and those notes may not make it back to the soldier's record. For these reasons many deployed studies have been self-report.[4,22,25,26] No method of injury capture is perfect and the drawback to self-report is that it will include minor injuries as well as those serious enough for the soldier to seek medical care or result in lost duty days.[27] A filter can be applied to these results to include only those that required medical care and or resulted in lost duty days.[27]

There has been some controversy as too what is the best injury capture method, medical record review or self-report surveys. Self-report data is subject to recall bias but then access to medical records is not always available or easy. In sports and in the military, patients can seek medical care from multiple sources not always included in medical records. Subjects can accurately recall whether an injury occurs or not over a 12 month period but accuracy decreased in their recall of the details.[28] Seventy-nine percent correctly recalled the number of injuries and body region injured while only 61% correctly remembered the diagnosis.[28] This is to be expected as most patients are not healthcare providers and it may be difficult to remember the medical terms associated with diagnoses. Even in those over 65 there was a moderate to excellent agreement between self-report surveys and medical records review.[29] The best method is capture recapture, a combination of the two which combines the accuracy in diagnoses found in medical records with the ability of self-report to pick up those injuries not included in the medical records.

1.1.3 Civilian Musculoskeletal Injuries

MSI are also a large problem in the civilian population as well as the military. Sports injuries alone account for over $1 billion dollars in annual healthcare costs worldwide.[30] Three to five million injuries occur every year in the US to competitive and recreational athletes.[30] Of civilian runners, 35% to 65% suffer a MSI.[31] The case definition of MSI varies from study to study in civilian studies. The most common case definition used in studies investigating athletes is an injury to muscle, bone, or joint requiring medical care and resulting in lost practice or game time, which is very similar to the military studies using MSI requiring medical care and resulting in lost duty days.[30] Women and men often suffer MSIs at different rates in the civilian populations as well as in the military. In a review of MSI, four studies found that female athletes had an increased incidence of injury compared to men.[32] A comparison of male and female professional basketball players, who would participate in daily physical training and be of a similar age range as soldiers, found that women suffered 60% more MSI than men.[33] Even when the rate of injury was similar between men and women the types of MSI are often different.[33] One study on indoor soccer players found that there was no difference in injury incidence between men and women but that men were at a three-fold increased risk of ankle injury compared to women and women were at a three-fold risk of knee injury compared to men.[34]

Two studies found that 33% of MSI in civilians were due to participation in exercise training or sports.[35,36] In order to investigate this, one study separated subjects into three categories: walkers, runners, and sport participants. MSI was self-report and defined as an injury to muscle, tendon, bone, ligament, or joint in the last 12 months.[31] The risk of MSI increased only in runners as frequency increased. Those running more than 1.25 hours a week were at greater risk of MSI than those running less.[31] Frequency had no effect on MSI for walkers or sport participants. In men, walkers, runners, and sport participants were all at increased risk of an activity related MSI compared to sedentary subjects whereas in women only runners were at greater risk.[31] While it seems fairly obvious that those participating in activity would be at greater risk of an activity related injury than sedentary subjects, it is interesting that only women runners were at increased risk. This study demonstrated that running can increase the risk of MSI at higher dosage.[31] A follow up study also found that 75% of men and 68% of women had to temporarily stop their exercise program and 31% of men and 24% of women had to permanently stop or change their exercise program showing the negative effects of MSI.[37]

Risk factors for MSI in civilians are similar to those seen in the military. Older age is often a risk factor in athletes (competitive and recreational) 18 years old and older.[7] In a study of female soccer players 14-39 years old, a very similar age range to soldiers, those over 25 were 3.5 times as likely to suffer an MSI as their younger counter parts.[32] Previous injury is also a common risk factor for MSI in civilians.[34] Three studies in civilian athletes found that those with lower aerobic fitness levels were at greater risk while two found no association and one found that those with higher aerobic fitness were at greater risk.[31,34] The study that found that those with higher fitness were at greater risk of MSI included subjects twice the age of those found in the military and used a treadmill aerobic test instead of a 1-2 mile run.[31] Only two studies in the civilian population found height, weight, or BMI to be a risk factor for injury whereas eight found no association between body composition and MSI.[30]

There are several studies that have noted a difference in injury risk based on skill level.[30] Those with higher skill levels are less prone to injuries.[30] This is a good justification for why just studying injuries in military training is not enough. Soldiers with higher skill levels/experience likely suffer injuries at a different rate and type than those in training, similar to their athletic counter parts. For example, stress fractures are one of the leading causes of injury in Basic Training but seldom seen in operational units.[7,9,20,38] Even in civilians MSI are a large problem. The incidence rate of MSI, types of MSI, and risk factors were often different in civilian men and women as they are in military men and women.[36]

1.2 BURDEN OF MUSCULOSKELETAL INJURIES IN THE US ARMY

1.2.1 Lost Duty Days due to Musculoskeletal Injuries

The large numbers of soldiers suffering MSIs can lead to a reduction in work efficiency, decrease in combat strength, and an increase in medical discharges from the US Army. The number of lost duty days from MSIs is higher than that of illness.[7,8,17] When a service member (member of one of the branches of the military) is injured they are evaluated by a medical provider. This medical provider can then give the service member a profile which is a form detailing specific restrictions to his or her duties. The number of days the medical provider prescribes the restriction for is considered the number of lost duty days as the service member is not able to function at full capacity. The average MSI can cause up to 18 days each of limited duty, roughly ten times the number of limited duty days due to illness.[7] Skeehan et al. found that 36% of 3,367 surveyed service members were given limited duty for an average of six days due to MSIs they suffered in the last year while deployed.[25] In the records review by Rhon, 10% of the physical therapy patients received limitations to duty lasting an average of 18 days in Iraq.[9] MSIs accounted for the most lost duty days during Desert Shield as well.[39]

The limited duty rate for women due to musculoskeletal injury can be significantly higher than men. In mechanics in operational Army units at Fort Bragg, 41% of men and 51% of women received limited duty for injury over one year.[20] Operational units are regular Army units with professional soldiers as opposed to training units where the solider is present only for a short period of time. Overuse injuries resulted in 80% of lost duty time in women in Marine Officer Candidate School.[19] Sprains caused the highest number of lost duty time in women but for men it was stress fractures in the US.[19] MSIs are reducing the work force stationed in the US and having the greatest impact on women.

Compared to all other health problems, MSIs cause the greatest reduction in combat readiness.[5] Skeehan et al. found 42% of surveyed service members had difficulty performing their duties due to injury and 19% of those injured could not perform their job at all and had to be replaced by other personnel.[25] Five percent of injured soldiers missed a combat patrol due to injury.[25] In a separate study, 21% of injured soldiers stated they had difficulty firing their weapon.[40] In a study by Sanders et al., 17% of 15,000 service members were unable to completely do their jobs due to injury.[4] Twenty-five percent of soldiers believed unit effectiveness had been negatively affected by injury.[4]

MSIs are clearly having a negative effect on our service members' ability to perform their occupational tasks especially in combat environments. Women lost more duty time from injury than men in studies conducted in non-deployed areas. Research is needed to support the creation of injury prevention methods in order to reduce the lost man hours due to injury especially in women.

1.2.2 Military Discharge and Economic Burden of Musculoskeletal Injuries in the U.S. Army

Beyond having a temporary effect on some soldiers' ability to work, MSIs can have a permanent effect as well. The medical discharge rate for the US Army has increased seven fold in the last 20 years.[14] When a service member is unable to fully recover from an injury to the point where he or she can perform his or her occupation, they are medically discharged from the military. The military will continue to pay for their medical care and provide a monthly disability payment as well. The rise in medical discharges is driven by an increase in discharges due to MSIs, especially those in women.[14,41] Musculoskeletal medical discharges in women have increased 8% a year compared to 5% for men and increased over 30 fold for women and over 17 fold for men from 1981 to 2005.[14] Twenty-nine billion dollars were spent on medical discharge payments in 2005 alone, most of which were a result of MSIs.[14] MSIs result in a large increase in medical discharges in women.

1.3 DIFFERENCES IN MUSCULOSKELETAL INJURIES BETWEEN MEN AND WOMEN

All studies done on service members in the US found that women had a higher incidence rate of MSI than men (Table 1). In a military wide study, women suffered more injuries than men in every category.[42] Studies in Basic Training populations have shown that 45% to 57% of women sustained a MSI whereas only 27% to 46% of men did.[43-45] The rate of overuse injuries in Basic

Training in women was 37.7% and in men it was 15.6%.[46] This difference in injury rates can be seen at multiple levels of training. Women were 10% more likely to suffer an injury in officer training than men.[17,19] In operational units, 29% percent of male and 47% of female Army mechanics suffered an overuse injury over a one year period.[20] The rate of overuse injuries resulting in lost duty days was significantly higher in operational unit female Army mechanics than male.[47] Female sex was found to be a risk factor for MSI in several other studies increasing the risk of MSI by more than 50%. [18,48,49] While MSI are a problem in men they are clearly having an even greater negative effect on women.

The case definition of MSI used by investigators seems to have affected incidence rates reported in the literature. Studies which include non-orthopedic injuries such as blisters, traumatic brain injury, and abrasions have higher incidence rates than those with just orthopedic injuries, Table 1. It is difficult to compare the injury rates across services or at different training levels because the case definitions tend to vary in these settings. The rate of injuries for the operational unit at the National Training Center was much lower than that of Marine Officer recruits despite using a similar case definition. The study conducted at the National Training Center included only injuries that were treated at the hospital and not those treated at the Aid Station, which is the first line of healthcare available to service members. The operational unit likely had a much lower injury incidence rate because most of the injuries were treated at the Aid Station and thus not recorded.

Case definitions covering only orthopedic injuries requiring healthcare and resulting in lost duty days are likely to provide a more accurate method of measuring the negative effect of these injuries on the military. The study on Army mechanics at Fort Bragg was the only operational unit to use this definition and 51% of women had MSI and 41% of men over a year, which are higher rates of injuries than most of the studies using a similar definition in Army Basic Training. Operational units may have a higher injury rate but there is very little research on injury rates in these units to verify this. In all cases, women still had a higher incidence of MSI regardless of the case definition used.

Not only do men and women suffer MSI at different rates, but also the types of MSI differ between men and women. The top five diagnoses in female officer recruits were ankle sprain, sprain of the arm/hand/shoulder, shin splints/lower leg, back/neck sprain, and knee sprain. In men it was ankle sprain, back/neck sprain, shin splints/lower leg, knee tendonitis, and hip strain.[17] In Marine Basic Training (13 week initial training for enlisted Marines) men and women had different types of lower extremity injuries. Women most often suffered retro-patellar pain syndrome, ankle sprain, and illiotibial band syndrome. Men differed slightly in the order of MSI and the type: Illiotibial band syndrome, ankle sprain, and Achilles tendonitis.[45] Female Army mechanics had significantly more lower extremity injuries resulting in lost duty days compared to men.[47] Similar to the incidence rates, the type of injuries are different in men and women and need to be studied separately.

1.3.1 Physical Activity vs. Physical Fitness

There is often some confusion when it comes to understanding the subtle differences between physical activity, exercise, and fitness and in epidemiological studies the terms are often incorrectly used interchangeably.[50] Physical activity is defined as movement of the body by the muscles that results in energy expenditure measured by kilocalories.[51] This includes a wide variety of activities: occupational tasks, sports, conditioning, chores, etc. “Exercise is a subset of physical activity that is planned, structured, and repetitive and has as a final or an intermediate objective the improvement or maintenance of physical fitness."[51] Physical fitness is specific measureable levels of health or skill such as aerobic fitness which can be measured by tests such as VO_2max.[51] Activities that fall into all three categories have been shown to be risk factors for MSI in service members.

Physical activity and physical fitness are intricately linked. More physical activity will generally lead to higher physical fitness.[50] There has been some argument as to what is more important, physical activity or fitness. Both have been show to decrease the risk of many chronic health problems such as diabetes and cardiovascular disease and death with the highest reduction in sedentary individuals who increase either.[52] The effects of fitness are graded. As fitness level increased, risk of disease and death decreased.[52] Physical activity, as little as one hour of walking a week, was also been shown to lower the risk of death due to cardiovascular disease.[52] Additionally, physical activity using as little as 45% of the heart rate reserve has been shown to halt or improve already existing cardiovascular disease and diabetes.[52] Physical activity of the level of mowing the lawn or greater was linked to lower risks of cancer.[52] According to multiple studies, both physical activity and fitness can lower the risk of morbidity and mortality but fitness is more important in lowering the risk of health outcomes than physical activity.[52-54] This could be in part due to the greater precision in physical fitness measurement as opposed to physical activity. Additionally, it is difficult to prescribe an exercise regime based on physical fitness improvement in regards to type, time, and intensity.[55] In the elderly, small increases in physical activity with no increase in aerobic fitness but increases in musculoskeletal fitness have been shown to help reduce chronic disease and disability.[52] Musculoskeletal fitness can have the same positive results on health risks as aerobic fitness.[52] For benefits to health the best approach may be a prescription based on physical activity level monitored by physical fitness measures.

A second definition of physical fitness is that it is the physiological state that allows one to meet the demands of daily living to include one's occupation.[52] Soldiers are well above the thresholds for the health benefits for physical activity and fitness. They are also not sedentary and most are not middle age or older as are most of the participants in the civilian studies. At this point, physical fitness becomes more important than physical activity for soldiers. Soldiers need to be physical fit enough to meet their occupational demands. In fact, physical training is designed to improve physical fitness with the goal of soldiers being able to perform their occupations successfully.

1.3.2 Causes and Activities Associated with Musculoskeletal Injury

Causes or activities associated with injury also differ between men and women. Overuse was the leading cause of injury in women whereas trauma was the leading cause in men in Advanced Individual Training.[20] Military training, work, recreation, and pre-existing conditions were the causes of injury most commonly cited by female rather than male soldiers.[56] PT, mechanical work, airborne landing, road marching, and garrison activities were the leading activities associated with injury in women while PT, mechanical work, sports, and airborne landing were the leading activities in men.[20]

1.3.3 Physical Training

PT was the leading activity associated with injury in both men and women and would fall into the subset of Physical Activity referred to as Exercise.[20] PT has been labeled the most important activity associated with injury and the first priority for intervention to reduce musculoskeletal injuries in the military.[57] Physical training has resulted in 25% to 50% of musculoskeletal injuries in the Army.[7,20,23,58,59] These injuries reduce the ability of the Army to accomplish its missions by decreasing available manpower. PT and sports are the leading cause of limited duty days as well in the Army.[10]

Research studies during Basic Training have investigated the effect of different PT programs on injury rates. Running was associated with the most PT injuries during initial training (62% of male PT injuries and 50% of female), more mileage led to 10-24% more injuries but not faster speeds.[60-62] Road marching mileage was substituted for running mileage without an increase in injuries or an increase in running times.[60,61] Reducing running mileage in initial training reduced stress fractures and saved $4.5 million in healthcare costs and 15,000 limited duty days in one year.[63] No studies have been conducted on injury rates and specific physical training methods outside the initial training setting. A soldier only spends the first year or less in initial training. It is known that PT is still a leading cause of injury outside training but studies have not been performed assessing the impact of specific PT training methods such as running or road marching mileage on injury rates. [8,22,30-32]

1.3.4 Risk Factors for Musculoskeletal Injury

Risk factors for MSI are often calculated for men and women together. Risk factors for injury calculated with both sexes combined included greater age, female sex, slower run times, fewer push-ups and sit ups, smoking, history of injury, and high running mileage.[8,18] Increased age, being a member of the National Guard, prior deployment, and midgrade enlisted rank (E5-6) increased the risk of injury while deployed in univariate analysis.[25] In multivariate analysis only multiple deployments, and midgrade enlisted rank were statistically significant predictors.[25] It is also important to establish the risk factors for MSI resulting in lost duty days. Fewer push-ups, slower run times, lower peak VO_2 max, and cigarette smoking were risk factors for time loss injuries in combined groups of male and female soldiers.[18]

Along with differences in MSI types, the risk factors for injury differ in men and women. In one Army Basic Training study, risk factors for injury resulting in lost duty days in women were shorter height, and slower run times and for men highest or lowest quartile of BMI, slower run times, fewer push-ups, and lower past self-rated activity levels (Table 2).[44] In a second Army Basic Training study using the same case definition, male risk factors for injury resulting in lost duty days were fewer push-ups, slower run times, lower peak VO2, cigarette smoking, less sit ups, high and low flexibility, and lower past exercise level (Table 3).[18] While risk factors for women were fewer push-ups, slower run times, lower peak VO2, and cigarette smoking.[18] In multivariate analysis risk factors for men were reduced to lower peak VO2, lower past exercise level, and smoking and for women the risk factors in the model were lower peak VO2 and smoking.[18]

In a more recent Army Basic Training study, Allison et al.[46] investigated personal risk factors for overuse injuries: acute/traumatic injuries were excluded, resulting in seeking medical care (Table 4). The case definition used in this study did not include lost duty days and did not capture injuries treated at the Aid Station (where the majority of minor injuries would be treated). Women who did poorly on the initial push-up test and initial run test were more likely to suffer an overuse injury.[46] Only push-ups (<4) remained a predictor in the logistic regression. Sit ups, age, height, weight, BMI, and rank were not predictors of overuse injury. Risk factors for men were push-ups, age, weight, BMI, number of dependents, and years of education. Four predictors for men were significant in the logistic regression: age (>25.5 years), BMI (>31.1 kg/m^2), more than two dependents, and less than 11.5 years of education.[46]

In Air Force Basic Military Training univariate risk factors for injury in women included higher BMI, slower run time, smoking, less running before Basic Training, lower educational level, and being married (Table 5).[64] Multivariate risk factors for women were 1.5 mile run slower than 18.24 minutes and being married.[64] In Air Force men univariate risk factors were less push-ups and sit ups, slower run times, smoking, and being divorced/separated.[64] Multivariate risk factors for men were 1.5 mile run time slower than 14 minutes and smoking.[64]

One study on an operational unit did investigate a few risk factors for injury but only looked at rank and type of unit. Additionally, this study included non-orthopedic injuries such as blisters and ingrown toenails in their case definition while not including Aid Station visits. In male soldiers during the five week training session at the National Training Center, being a member of a Combat Service Support unit and being enlisted were both risk factors for injury and illness combined while in female soldiers both Combat Support and Combat Service Support units had increased risk compared to Combat Arms and only lower enlisted (E1-4) were at greater risk than officers for injury and illness.[65]

Finally, when injuries cannot be rehabilitated they result in medical discharges. In men risk factors for disability discharge for overuse injuries include shorter length of service, older age, more physically demanding occupations, and higher work stress.[66] In women risk factors for disability discharge from the military included only high school level education as opposed to college.[66]

The most commonly found risk factors for women in these training populations were only fitness measures. They were fewer push-ups and slower run times with slower run time being the most common. In men the most consistently found risk factors were older age, fewer push-ups and sit ups, slower run time, and extremes of BMI. None of these studies assessed if elements of the PT program itself were leading to injury and no operational units were investigated beyond assessing rank and unit type. Because of the differences in the risk factors for MSI, types of MSI suffered, and causes of MSI; studies should investigate these variables in men and women separately and with the paucity of literature on risk factors in operational units more research is direly needed in this area in order to begin to create prevention programs.

1.3.5 Demographic and Body Composition Risk Factors

There are several common demographic risk factors for injury in female service members. Lower rank is a risk factor in women with the lowest enlisted ranks being at the highest risk.[65] Smoking has been shown to be a risk factor in female service members as well.[18,64] In both univariate and multivariate analysis multiple deployments was a statistically significant predictor of injury in deployed service members.[25] While age has not been shown to be a risk factor for injury in military women, it was a risk factor in men and civilian women.[8,32,46] Shorter height and higher BMI are physical risk factor in female service members.[16,64] History of low back pain was found to be a risk factor for future episodes in military recruits.[67] In fact, those with a previous low back injury are at three to six times greater risk of re-injury.[68] History of past injury was also a predictor of injury in military personnel.[8] These factors need to be studied in women in an operational unit.

1.3.6 Fitness and Physical Training Risk Factors

Fitness level measured in different fashions was shown to be a risk factor for injury in women. Again, fitness is a measurable health or skill related attribute while exercise, PT, is expending energy with the goal of improving or maintaining fitness.[51] The Army Physical Fitness Test is a fitness measure and quantifies the soldiers' upper and lower body muscular endurance.[69] The Army Physical Fitness Test includes, in order, two minutes of push-ups, two minutes of sit ups, and a two mile run. The soldier's shoulders must reach the height of her elbows in order for the push-up to count. The soldier is not allowed to lift her hands or feet off the ground and cannot place her knees on the ground or the event is terminated. Previous studies on push-ups indicate a good correlation with total upper body strength and endurance.[70] Fewer push-ups were a risk factor in training environments for women.[18,46] The base of the soldier's neck must reach the vertical plane created by the base of her spine during sit-ups and the soldier is only allowed to rest in the up position. The two mile run is commenced within ten minutes of finishing the sit-ups. While walking is allowed, it is highly discouraged. The two mile run has shown good or excellent correlation to VO_2max in subjects.[70,71] Slower run times on 1 mile, 1.5 mile and 2 mile runs were risk factors for injury in training.[18,44,46,64] The composite score is calculated by adding the adjusted score for each event. Raw score for each event (number of push-ups and sit-ups and run time) is converted to scores using a age stratified table.[69] Total Army Physical Fitness Test score has been found to be a predictor of low back injury in soldiers but was not analyzed separately for each sex or for MSI in general.[49] Lower self-reported fitness level has been reported as a risk factor for sprains, strains, and back pain in police officers as well as service members.[72] This study also found that police officers reporting higher intensity levels of training were at less risk for back pain while those who were obese were at greater risk.[72] Similar results were found in fire fighters. Those with higher levels of fitness were at less risk of back pain.[73] Neither of these studies looked at differences between men and women. Future research is needed on the fitness level as a risk factor for injury in operational units.

Not only are modifiable individual risk factors such as fitness level or BMI useful for the development of injury prevention methods but so are modifiable PT risk factors such as frequency, duration, and intensity. More strength training was found to be a risk factor for injury in deployed soldiers but less strength training was a risk factor for stress fracture in female Marines.[22,45] In training environments, more running mileage led to more injuries but not faster speeds.[60-62] Reducing the running mileage decreased the number of injuries in female soldiers by over 10% with no reduction in running speed.[60] Road marching was used to replace running mileage and suggestions have been made to incorporate more agility training into physical training but no research has been done to see if these had any effect on injury rates or what the results would be in operational units as opposed to training units.[60,63]

1.4 PREVENTION

According to the US Army Public Health Command there are five steps to injury prevention: 1) Surveillance, 2) Research on risk factors, 3) Research on intervention, 4) Program and policy implementation, and 5) Evaluation and monitoring of programs/policies.[5] At this point there is quite a bit of surveillance and research on risk factors for injuries due to physical training for men and women in basic training and some for officer training. There is some research on interventions used at this level.[60,74] There is very little surveillance and risk factor research on operational units and none of them have looked at PT even though it is the number one cause of injury.[7,20,23] Soldiers only spend a very small portion of their career in training. The majority of their injuries from PT are likely coming from their time in operational units. These injuries result in lost duty days and medical discharges.[7-10,14,41] In order to prevent these injuries, first surveillance and research on risk factors in operational units must be conducted.

1.5 PUBLIC HEALTH SIGNIFICANCE

MSI account for the highest healthcare utilization, most medical evacuations, most lost duty days, and most medical discharges.[1,7-10,14,75] These MSI negatively affect unit morale and reduce combat readiness.[4,5] Billions of dollars are spent annually on medical discharge payments for MSI.[14] These figures do not even include the cost of training replacements for permanently injured soldiers which is an average of $50,000 per military member.[76] These injuries result in a huge economic burden being transferred to the US tax payers in the form of medical evacuations, treatment, disability payments, and training of replacement personnel, which when all combined result in billions of dollars annually.[5,14,76,77] MSI are clearly a very large problem resulting in high medical and disability costs as well as lost manpower. Research on risk factors for these MSI could reduce MSI and the negative consequences to the individual, the US military, and society at large.

MSIs cause a serious drain on resources and decrease the combat effectiveness of units.[4,25,40] In the military, men and women suffer musculoskeletal injury at different rates (with women being at greater risk than men), have different types of injuries, and have different risk factors for injury.[8,42,46] These musculoskeletal injuries have led to the rate of medical discharges increasing seven fold with the increase in musculoskeletal discharges in women increasing at twice the rate of men over a 20 year period.[14] Almost all research on these risk factors, especially the effects of PT on injury, have been done in training environments even though the majority of a soldier's career is spent in operational or regular military units. In order to begin to address the large number of musculoskeletal injuries occurring in female soldiers, risk factors must first be identified to allow the creation of properly targeted prevention programs.

Table 1. Comparison of Multiple Military Injury Studies

Women	Men	Location	Length of Training	Case Definition	N (Men/ Women)	Analyzed Male/Female Risk Factors
70%	65%	Marine Corps Basic Training	11 weeks male, 12 weeks female	Lower extremity MSI only, sought medical care or completed a survey followed by evaluation if an unreported injury was identified in the survey[45]	176/241	No
80%	60%	Marine Officer Candidate School	6 Weeks	MSI and sought medical care (included blisters, TBI, ingrown toenail, abrasions, contusions)[19]	459/30	No
38%	16%	Army Basic Training	9 weeks	Overuse MSI with hospital visit, did not include Aid Station visits[46]	518/416	Yes
41%	17%	Army Basic Training	8 weeks	MSI and sought medical care and resulted in lost duty days[43]	509/352	No
64%	29%	Army Basic Training	9 weeks	MSI and sought medical care and resulted in lost duty days[18]	733/452	Yes
45%	29%	Army Basic Training	8 Weeks	MSI and sought medical care and resulted in lost duty days[44]	124/186	Yes
67%	43%	Air Force Academy	6 weeks	MSI and sought medical care[17]	986/224	No
46%	27%	Air Force Basic Military Training	6 weeks	MSI and sought medical care[64]	1979/723	Yes
61%	44%	Afghanistan	12 months	Self-report MSI[22]	536/57	No
51%	41%	Fort Bragg, 63Bs	12 months	MSI and sought medical care and resulted in lost duty days[20]	518/43	No
11%	6%	Army National Training Center	5 weeks (rate is per week)	MSI and sought medical care (included blisters, TBI, ingrown toenail, abrasions, contusions, and environmental injuries) did not include Aid Station visits[65]	4101/413	No

MSI – musculoskeletal injuries.
TBI – traumatic brain injury.
63B – military occupational specialty code for Army mechanics.

Table 2. Risk Factors for Injury during 8 Week Army Basic Combat Training

Univariate Risk Factors	
Women	**Men**
Shorter height	High and low BMI
Slower run time - 1 mile	Less push-ups
	Slower run times – 1 mile

From Jones et al[44]
Injury definition – musculoskeletal injury requiring medical care and resulting in lost duty days.
Army Basic Training – 8 weeks.

Table 3. Risk Factors for Injury during 9 Week Army Basic Combat Training

Univariate Risk Factors	
Women	**Men**
Less than 14 push-ups	Older than 25 years
Slower than 19:49 on 1.5 mile run	Less than 32 push-ups
Low VO2 max	Less than 32 sit ups
Smoke more than 20 cig/day	Slower than 17:14 on 1.5 mile run
	Low VO2 max
	Sit and reach less than 28 cm or greater than 35 cm
	Smoke more than 11 cig/day
	Less physical activity before Basic
	Sports or exercise <1/week before Basic Training
Multivariate	
Low VO2 max	Low VO2 max
Smoking Yes	Sports or exercise <1/week before Basic Training
	Smoking Yes

From Knapik et al[18]
Injury definition – musculoskeletal injury where the soldier sought medical care and lost duty days.
Army Basic Training – 9 weeks.

Table 4. Risk Factors for Injury during a Second 9 Week Army Basic Combat Training

Univariate Risk Factors	
Women	**Men**
Less push-ups	Less push-ups
	Older age
	Heavier weight
	Higher body mass index
	More dependents (spouse and children)
	Less years of education
Multivariate	
Less Push-ups	Older age
	Higher body mass index
	More dependents
	Less years of education

From Allison et al[46]
Injury definition - Overuse musculoskeletal injury requiring a hospital visit, did not include Aid Station visits.
Army Basic Training - 9 weeks.

Table 5. Risk Factors for Injury during 6 Week Air Force Basic Military Training

Univariate Risk Factors	
Women	**Men**
Ran less than once per week before Basic Training	Low body mass index
Ran slower than 18.23 for 1.5 miles	Less than 28 push-ups
1-9 cigarettes per day	Less than 30 crunches
	Ran slower than 12.63 for 1.5 miles
	Smoked in the last 30 days
	10 or more cigarettes per day
Multivariate Risk Factors	
Ran slower than 18.23 for 1.5 miles	Ran slower than 12.63
Married	Smoked in the last 30 days

From Knapik et al[64]
Injury definition – musculoskeletal injury requiring medical care
Air Force Basic Military Training – 6 weeks.

2.0 RESEARCH DESIGN

2.1 SPECIFIC AIMS

The purpose of this study is to investigate the demographic, body composition, fitness, and physical training risk factors for musculoskeletal injuries in female soldiers serving in operational Army units over a 12 month period.

2.1.1 Specific Aim 1

To explore the MSI sustained by female soldiers.

Research Question 1: Describe the most recent MSI sustained by female soldiers in the 4th Infantry Division over a one year period while serving at an US Army installation.

Hypothesis 1.1: The greatest proportion of MSI will occur in the low back anatomical region.

Hypothesis 1.2: The greatest proportion of MSI will be associated with the self-reported activity running.

2.1.2 Specific Aim 2

To determine the demographic and body composition risk factors for MSI in female soldiers.

Research Question 2: What are the demographic and body composition risk factors for MSIs resulting in lost duty days in female soldiers in the 4th Infantry Division serving at a US Army installation over a one year period.

Hypothesis 2.1: Of all the demographic variables, lower rank and higher age will be positive predictors for MSI.

Hypothesis 2.2: Of all the body composition variables, higher body mass index will be a positive predictor of MSI.

2.1.3 Specific Aim 3

To determine fitness and physical training risk factors for MSI in female soldiers.

Research Question 3: What are the fitness and physical training risk factors for MSIs resulting in lost duty days in women serving at a US Army installation over a one year period.

Hypothesis 3: Of all the fitness and physical training variables, 2 mile run time, higher weekly running mileage, and less strength training will be positive predictors of MSI.

2.1.4 Specific Aim 4

To determine the demographic, body composition, fitness, and physical training risk factors for MSI in female soldiers.

Research Question 4: What combination of demographic, body composition, fitness, and physical training variables best predict MSIs resulting in lost duty days in female soldiers in the 4th Infantry Division serving at a US Army installation over a one year period.

Hypothesis 4: Of all the variables; rank, frequency of runs, and 2 mile run time will best predict MSI in female soldiers.

2.2 METHODS

2.2.1 Overview of Methods

In August 2010, US Army Public Health Command (USAPHC) was tasked by the Army Office of the Surgeon General to provide support to the 4th Infantry Division (ID). Office of the Surgeon General requested an evaluation of PT with regard to effects on injuries and fitness. A team of four epidemiologists at the US Army Public Health Command used previously utilized surveys as a starting point for survey development.[20,22,78] They combined portions of these surveys and added additional questions in order to capture the information requested by the Office of the Surgeon General. The first section of the survey inquired about demographic information, the next section is on unit PT (mandatory group PT), followed by personal PT (voluntary exercise done during off time), tobacco use, nutrition, and injuries. This survey was then sent to several other researchers in the military injury field for review and comment. Suggestions were incorporated into the next draft of the survey. The survey was tested for understandability on soldiers stationed at Aberdeen Proving Grounds. Adjustments were made to improve the readability of the survey for soldiers. This version of the survey was then used on the first Brigade Combat Team (BCT) to be tested. Slight modifications were made on the survey before each of the next two brigades were surveyed. Questions were added to capture new information requested by Office of the Surgeon General. The psychometrics of the survey were never tested (it was not validated). Only data from questions that were consistently on all three versions of the survey were provided for the current protocol.

Retrospective data in the form of a self-report survey was collected from three brigades within the 4th ID. Each brigade was queried separately over a two year period, 2011 through 2012. Soldiers were informed of the opportunity to participate but participation was not mandatory. In each case, the soldiers reported to an auditorium over a one week period to fill out the questionnaire. Each brigade had a different one week period. They were given instructions on how to fill out the survey and were allowed to ask questions before and while completing the survey. Soldiers were required to finish the questionnaire in one sitting. Soldiers were asked to provide information about demographics, physical traits, Army Physical Fitness scores, physical training, and any MSI suffered over the last 12 months. This project was determined not to be research by the Office of Human Protections at US Army Public Health Command and no informed consent was required.

Once the data was collected, a scanner was used to enter the data into electronic format. The electronic data was then compared to the hard copy to ensure no errors were made. Data was then converted into SPSS format. Of the data collected by the US Army Public Health Command, this study will investigate the female soldiers only. Additionally, data on nutrition will not be analyzed as it is being used by the US Army Public Health Command for a separate manuscript. The raw Army Physical Fitness scores and soldiers' ages were provided. These scores were converted into total scores using the US Army Physical Fitness scoring table.[69] Those identified as injured by the US Army Public Health Command will be looked at and assessed as to whether or not they have a MSI that meets the definition used in this study. Those that do not have a qualifying MSI will be relabeled as not injured. The US Army Public Health Command agreed to share the surveys from the female soldiers with the University of Pittsburgh for the purpose of this protocol. The University of Pittsburgh determined that this protocol was exempt and a data use agreement was executed between the University of Pittsburgh and US Army Public Health Command.

2.2.2 Participant Population

Six hundred and twenty five females volunteered for this study. Table 6 contains the demographic information. This was 43% of the women in Red brigade, 69% of the women in White brigade, and 54% of the women in Blue brigade. If the opportunity to participate was better disseminated in one brigade as opposed to another, that could account for the difference in participation. There is a possibility for selection bias here with these reporting percentages. It is possible that brigades sent a higher percentage of injured women as these soldiers tend to be working in the offices due to their injury are easily accessible. Additionally, if one brigade had very few injured soldiers, this brigade may not have understood the importance of the study and may not have actively encouraged the women to participate.

Inclusion Criteria – Soldiers must be female and permanently assigned to the 4th ID.

Exclusion Criteria – Male soldiers and female soldiers not permanently assigned to the brigade were excluded.

2.3 STATISTICAL ANALYSIS

2.3.1 Primary Outcome Variable

The original definition of injury used by the US Army Public Health Command is as follows. "People can be injured accidentally or on purpose. Injuries can occur in two ways:

1) When strong sudden forces are applied to the body – these would include things like falling from a ladder, an automobile crash, or being hit by a bullet fired from a weapon.

2) When smaller forces are applied to the body over and over again (repeatedly) – these would include activities like excessive exercise or running long distances, repetitive lifting/pulling/pushing objects, or repeatedly pitching a softball. With these definitions in mind, have you had an injury during the past 12 months? If so, how many different times did you have an injury where any part of your body was hurt, for example, joint sprains, muscle or tendon strains, concussion, cut finger, broken bone, or shin splints? Using this definition the USAPHC found 330 women with injuries or 53% of the sample."

In the current study a more precise definition of injury will be used. Musculoskeletal injury will be the dependent variable. This will be defined as an orthopedic injury to muscle, bone, or nerve that results in a restriction to duty issued by medical personnel. It is common practice in most military studies to include duty restrictions in the definition of musculoskeletal injuries in order to incorporate a measure of severity as well as a measureable outcome related to unit productivity.[18,43] Intentional injuries, heat or cold injuries, blisters, concussion, amputations, and injuries due to being struck by something will not be included as they were not included for the majority of the studies in Table 1. To exclude these injuries, three questions from the survey will be investigated, Table 7. The first question is whether the injury was accidental or intentional. Intentional injuries will be excluded, as things such as amputations and gunshot wounds are unrelated to physical training or fitness. The second question is as to the type of injury. Superficial injuries such as bruises, scrapes, cuts, and blisters were not included. Additionally concussions, amputations, burns, and heat or cold injuries were also excluded. Sprains, strains, dislocations, fractures, tendonitis, nerve injury, and pain will be included. The third question concerned how one was injured. If the cause was being struck, cut, fire or hot substance, environmental factors, or breathing or swallowing dust, they will be excluded as well. Falls, jumps, trips, overexertion, repetitive motions, and other will be included. Participants with any of the excluded answers will be marked as not injured for the purpose of the current study. If subjects selected more than one answer and selected one of the included answers and one of the excluded answers they will be included as injured to decrease the chance of excluding possible injuries. Of the 625 women, 186 (30%) had a MSI resulting in a restriction to duty issued by a medical provider. When comparing the demographics of those injured according to the US Army Public Health Command definition to those injured with the current study definition there was no difference (Table 8).

2.3.2 Injury Variables

All variables were self-report.

1) Whether or not the soldiers suffered an injury in the last 12 months according to the US Army Public Health Command definition which was a yes or no question

2) The number of injuries suffered in 12 months, this was a continuous variable.

3) The type of injury to include sprains, strains, dislocations, fractures, tendonitis, nerve injury, and pain.

4) The anatomical body part injured to include head, neck, shoulder, arm, elbow, wrist, hand, chest, upper back, abdominal area, lower back, hip, pelvic area, thigh, knee, lower leg, ankle, and foot. Soldiers did not supply the diagnosis for their injury only the body region injured. Due to this, it would not be possible to identify soldiers with radicular low back pain or meniscal tears only soldiers with an injury to the low back or the knee.

5) Duty status was determined by asking the soldier if s/he was on duty (working or doing PT) or off-duty (leisure time) when the injury occurred.

6) The activity associated with MSI was limited to riding or driving a vehicle, exercise, sports, walking/hiking/road marching, lifting, working on vehicles or equipment, and other.

7) The cause of the injury question offered the following responses: fall, jump, trip, or slip; struck against or struck by an object or person; cut by a sharp instrument, tool or object; overexertion, strenuous, or repetitive movements; fire, hot substance or object, or steam; environmental factors such as heat or cold, breathing or swallowing dust, particles, liquid vapors, or fumes; or other.

8) Soldiers were asked if they sought medical care yes or no.

9) Soldiers were asked if they were hospitalized for the injury and for how many days.

10) Soldiers were asked if they received a limited duty profile for their MSI and for how many days.

2.3.3 Independent Variables

All variables were self-report.

Demographic Variables

1) Age will be measured in years. Soldiers provided their birthdate and the age at the time of the survey was calculated from this prior to the data being transferred to the University of Pittsburgh. The University of Pittsburgh data has age only as a continuous variable and not the birthdates.

2) Rank was provided by each soldier. Ranks were entered as E1-9, O1-10, and WO1-5. These were not categorized.

3) The number of previous deployments was provided by each soldier. This question was categorized. Soldiers could answer 1, 2, or 3 or more.

4) Soldiers were asked if they currently smoked cigarettes or not. This was a yes or no response.

Body Composition Variables

1) Height was reported in feet and inches, for example 5' 4" and is a continuous variable. This was converted into solely inches.

2) Weight was reported in pounds and is a continuous variable.

3) Body Mass Index was calculated by the US Army Public Health Command from the reported height and weight and recorded in kg/m^2 and is a continuous variable.

Fitness Variables

1) The composite Army Physical Fitness score was calculated as a continuous variable. Again, fitness is a measurable health or skill related attribute while exercise, PT, is expending energy with the goal of improving or maintaining fitness.[51] The Army Physical Fitness Test measures the soldiers' upper and lower body muscular endurance.[69] The Army Physical Fitness Test

includes, in order, two minutes of push-ups, two minutes of sit ups, and a two mile run. There are a total of 100 points available in each category. The composite score is calculated by adding the adjusted score for each event. The raw score for each event (number of push-ups and sit-ups and run time) is converted to scores using a age stratified table published by the US Army.[69] Score weighting changes every four years as a soldier ages.

2) Push-up raw score was provided as the total number completed in 2 minutes and is a continuous variable.

3) Sit up raw score was provided as the total number completed in 2 minutes and is a continuous variable.

4) Two Mile run time was reported as the total time required to run 2 miles and is a continuous variable.

5) Passing or failing the Army Physical Fitness Test was calculated by looking at the weighted score of each event. A weighted score of at least 60 in each category is required to pass. If the soldier scores less than 60 in any one category, the Army Physical Fitness Test is considered a failure.

<u>Physical Training Variables</u>

1) Participation in unit PT was recorded as yes or no. Unit PT is conducted as a group usually for 1 to 1 ½ hours in the morning. This is mandatory for most soldiers.

2) Frequency of unit PT was reported as categorical responses: less than 5 times a week, 5-7 times a week, 8-14 times a week, more than 14 times a week. This variable was categorical.

3) Frequency of calisthenics (push-ups, jumping jacks, etc), strength training (weights, kettle bells, etc), agility training (jumping, sprinting with direction changes, obstacle courses, etc), and sprint training (bursts of speed in the forward direction) were each reported as one of the

following options: none, 1-2 times a week, 3-4 times a week, more than 4 times a week. This is a categorical variable.

4) Frequency of road marching was also reported as one of the following categories: none, once per month, 2 times per month, 3 times per month, 4 or more times per month and is a categorical variable. Road marching consists of walking or running along a designated path while wearing a ruck sack and often body armor. A weapon may or may not be carried as well. The road march is typically performed in Army Combat Uniform with boots and helmet. Field Manual 21-18 details the specifics of road or foot marching.[79]

5) Average distance of road march was reported as one of the following responses: 0, 1-3 miles, 4-6 miles, 7-10 miles. This is a categorical variable.

6) Average weight of load for road march was reported as 0-15 lbs., 16-30 lbs., 31-50 lbs., 51-75 lbs., more than 75 lbs.

7) Frequency of unit runs was categorized as none, 1-2 times a week, 3-4 times a week, 5 or more times a week

8) The average distance of unit runs was reported as 0, 1-3 miles, 4-5 miles, 6 or more miles

9) Soldiers were asked if they participated in PT on their own yes or no. This question is asking if the soldier does voluntary PT (as opposed to unit PT which is group run and mandatory).

10) The frequency of personal strength training could be none, 1-2 times a week, 3-4 times a week, or more than 4 times a week.

11) The frequency of personal sprint training was reported as none, 1-2 times a week, 3 or more times a week.

12) The frequency of personal runs was reported as none, 1-2 times a week, 3-4 times a week, 5 or more times a week

13) The average distance of personal run could be 0, 1-3 miles, 4-5 miles, or 6 or more miles.

14) Three compound variables were created for running mileage. Because the categories overlap if they are combined, the average value of each answer was used. Using these single number averages unit run distance per week was calculated by multiplying the frequency of unit runs by the average mileage. Personal run distance per week was calculated in the same manner by multiplying the frequency of personal runs by the average mileage. Finally, the total weekly unit mileage was added to the total weekly personal mileage to get the total weekly mileage.

2.3.4 Hypotheses Analysis

Specific Aim 1

Hypothesis 1: The greatest proportion of MSI will occur in the low back anatomical region and the greatest proportion of MSI will be associated with the self-reported activity running.

MSI will be described as a percentage of the total for body region injured and reported activity associated with injury. The number of injuries in each body region will be divided by the total number of injuries in order to obtain the percent of injuries occurring in each region such as the low back. The number of injuries associated with each activity will be divided by the total number of injuries to obtain the percent of injuries occurring during each activity such as running. A chi square test for goodness of fit will then be performed to assess if there are significant differences in frequencies between the categories. Pairwise comparisons will then be performed to assess where any differences lie.

Specific Aim 2

Hypothesis 2.1: Of all the demographic variables, lower rank and higher age will be positive predictors for MSI.

Hypothesis 2.2: Of all the body composition variables, higher body mass index will be a positive predictor of MSI.

We will use three steps for the inferential statistical analysis for specific aim 2. This will be done once for MSI resulting in lost duty days only.

Step 1 will consist of analysis of univariate correlation of each independent variable and injury incidence. Continuous variables will be analyzed using point bi-serial correlation, whereas categorical variables will be analyzed with chi square test of independence. Dependent variables with a p-value of 0.1 or less will be considered for input into the logistic regression in step three.

Step 2 will consist of the calculation of relative risk (RR) for all variables. For step 2, the continuous variables will be collected and organized into categorical data to allow the calculation of RR. The level least likely to result in injury will serve as the standard or baseline to which the other will be compared. Continuous variables will be categorized using functional categories.

Step 3 will consist of logistic regression. Variables from 2.1, 2.2, and 2.3 found to have an association to injury with a p-value ≤ 0.1 during step 1, or a significant change in risk during step 2, will be considered for the simultaneous logistic regression in order to establish the logistic model best able to predict injury. If the continuous variable was associated with injury it will be input into the regression as continuous. If only the relative risk was significant, the variable will be input into the regression in the categorical form used to calculate the relative risk. The All Subset method will be used to determine the best logistic regression model.

<u>Specific Aim 3</u>

Hypothesis 3: Of all the fitness and physical training variables, slower run times, higher weekly running mileage and less strength training will be positive predictors of MSI.

Statistical analysis will be performed in the same three steps as Hypothesis 2 but for the physical training variables.

<u>Specific Aim 4</u>

Hypothesis 4: Of all the variables; rank, frequency of runs, and 2 mile run time will best predict MSI in female soldiers.

Statistical analysis will be performed in the same three steps as Hypothesis 2 but for all the variables together: demographic, body composition, and the fitness and physical training variables.

2.3.5 Sample Size and Power

With 625 women and an injury rate of 30% and alpha=0.05, an odds ratio of 1.82 can be detected with 0.8 power using logistic regression.[80] These same parameters will detect a small difference in means between groups on continuous variables, d=0.25, and 0.81 power.[81] For chi square test of relationship with categorical variables, the current sample has a power of 0.84 with 3 degrees of freedom and alpha=0.05 of detecting a small effect size, w=1.4, and no variable in the sample has more than four levels.[81]

2.4 LIMITATIONS

This study has several limitations. Although we believe our sample is representative of the overall military populations found in the US Army, our study would not be generalizable to civilian populations. The generalizability to the overall Army population is supported because we included an entire Brigade Combat Team. These brigades are designed to be able to operate independently and they include almost every type of soldier from clerks to snipers. A second limitation is that variables were self-reported which could have introduced the possibility for recall bias and makes it difficult to get an accurate measure of the subjects' physical activity. This makes it difficult to ascertain if there is indeed a relationship between physical activity level and MSI when the physical activity levels are not accurate. Self-report is not as much of a concern for recall bias in terms of fitness measures. It was found that self-reported Army Physical Fitness Test scores are at most only 10% off from the soldier's actual Army Physical Fitness Test.[82] Self-report could also result in the responses concerning MSI not being as accurate as those found in the medical records. It does, however, offer the advantage of picking up injuries that may not be in the electronic records. In some cases, soldiers will be seen by medical providers and only a written note will be completed. Using self-report would increase the accuracy of our study when the physician's assistants were doing paper notes. A third limitation is that the majority of the survey only offered categorical choices for answers and did not allow the soldier to enter a number which would have created continuous variables. Continuous variables are more accurate and have more power when used in analysis. It is more difficult to determine if there is a dose response relationship between variables and MSI with categorical variables. A fourth limitation is that the diagnoses were not included. This limits the ability of this study to be compared to other studies including the diagnoses and also does not allow the most common diagnosis to be identified. Data is limited to the body region only. Fifth, the definition of injury in this study included all body regions. Performing the analysis on individual body regions might result in more specific risk factors. Including multiple diagnoses and body regions as one category, MSI, makes it more difficult to find MSI predictors as back injuries and ankle injuries may have different predictors and when combined into one category the predictors are likely only those that they have in common. This is also true for diagnoses even within in one body region. Predictors for anterior cruciate ligament tears are likely different than those for herniated disks in the thoracic spine. A sixth limitation is that only information is provided for the most recent injury which limits analysis to that injury only. A seventh limitation to this survey is that because this survey only investigated a 12 month period, it was nearly impossible for those who had no MSI to have a history of injury (they had not had an injury during the 12 months that met our case definition and were not queried as to their history before that). Those that had more than one injury over 12 months had a history of injury. If their most recent injury did not meet our case definition they were considered uninjured but with a history of injury. If they had more than one injury over 12 months and their most recent injury did meet our case definition, then they were considered injury with a history of injury. This method would result in an undercount of those with a history of injury and create an inflation of the risk of injury in those with a history of injury. Additionally, it resulted in a probable undercount of the number of soldiers with MSI because if their most recent injury did not meet our case definition we did not have any information on the other injuries they had over the last 12 months, one of them might have qualified as an MSI. Eighth, the survey was not validated. The psychometrics of this survey were never tested. It is not known how well the questions truly measure physical activity. Tenth, while this study was retrospective, it is possible that a lot of the answers on the physical activity variables were cross sectional. For example, those currently on limited duty may have stated that they perform no running but in reality they were running before the injury. This could result in physical activity variables being deflated; the average amount of running for those injured would be lowered if many of them were reporting their running values after injury instead of before. This could cause the U shaped result that we found where no unit runs or 3 or more unit runs were not protective. Last, there may be other important risk factors not measured in our study, especially occupational factors (e.g., weight of objects lifted, time spent sitting) and psychological factors such as depression and stress that may contribute to the prediction of MSI.

3.0 RESULTS

Of the 625 women, 330 (54%) of the population has an injury using the US Army Public Health Command's more broad case definition. Using this definition there were an average of 2 injuries per person, figure 1, this information was not available for the more restrictive case definition used in this study. Of the 625 women, 186 (30%) suffered a MSI over a 12 month period using our case definition. The MSI resulted in an average of 69.8 days of limited duty per MSI and a median of 30 days, figure 2. This included the 11,162 limited duty days for 160 injuries, 26 injuries did not list the number of limited duty days. If we exclude those who had limited duty for the entire year then there were 7,877 limited duty days for 151 MSI, 52.2 days per MSI. The demographics and means and standard deviations of the continuous variables for the sample are in Table 9. Of these, 117 (63%) were caused by overuse; 61 (33%) were due to a fall, jump, trip, or slip; and 8 (4%) were other. Table 10 depicts the self-reported types of injury sustained by the women. The majority of injuries were identified as strains or sprains by the women.

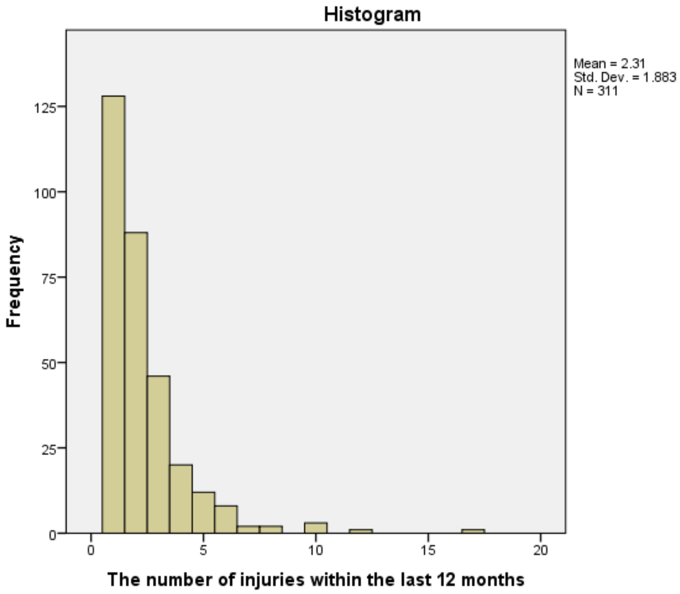

Figure 1. Distribution of the number of injuries per soldier during the last 12 months using the US Army Public Health Command's case definition

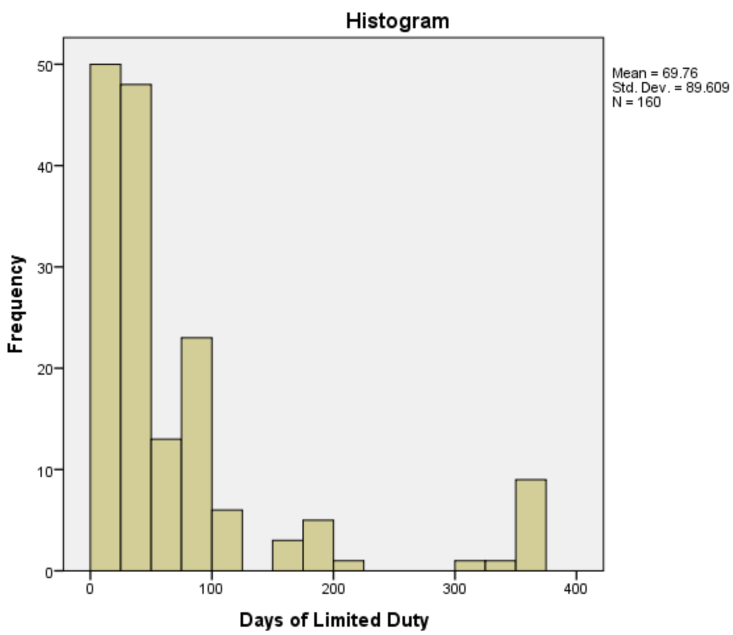

Figure 2. Distribution of limited duty days

3.1 SPECIFIC AIM 1

Hypothesis 1.1: The greatest proportion of MSI will occur in the low back anatomical region.

Hypothesis 1.2: The greatest proportion of MSI will be associated with the self-reported activity running.

The anatomical region injured for each participant can be found in Table 11. Chi squared test was used to assess differences in frequency. There was a significant difference between the proportions of injuries in each body region $\chi 2$ (8)=27.71, p=0.001. The low back was not the most frequently injured body region. The most injuries occurred in the ankle, 13%, but this was not significantly more than the number of injuries to the low back (7.5%), $\chi 2(1)=2.63$, p=0.105. There was only a significant difference between the number of low back and upper back injuries (2.7%), $\chi 2(1)=4.26$, p=0.04. If all the lower extremity injuries are combined from the hip to the foot, there are significantly more lower extremity injuries than low back injuries, $\chi 2(1)=61.127$, $p<0.001$. Table 12 shows the frequencies of which each activity was reported to be associated with injury. There was a significant difference between the proportions of injuries in each category of activity, $\chi 2(8)=130.58$, $p<0.001$. Running caused significantly more injuries than any other category; the chi squared test comparing running to the next closest category, lifting and moving heavy objects, was $\chi 2(1)=17.48$, $p<0.001$.

3.2 SPECIFIC AIM 2

Hypothesis 2.1: Of all the demographic variables, lower rank and higher age will be positive predictors for MSI.

Hypothesis 2.2: Of all the body composition variables, higher body mass index will be a positive predictor of MSI.

Of all the continuous demographic and body composition variables only rank and age were significantly correlated with MSI, Table 13. Of the categorical demographic or body composition variables only history of injury was significantly associated with MSI, $\chi 2(1)=63.783$, $p<0.001$, Table 14. Of the categorical demographic and body composition variables, brigade, history of deployment, and number of times deployed all had p-values < 0.1.

Relative risks were calculated for all demographic and body composition variables, Table 15. The lowest ranks, E1-4, were at significantly greater risk than officers/warrant officers, RR=1.676 (CI 1.013-2.773). Women in the blue brigade were at significantly higher risk than those in the red brigade, RR=1.481 (CI 1.073-2.042). Women with no history of deployment were at greater risk of injury than those with two or more deployments, RR=1.475 (CI 1.022-2.131).

Brigade, history of deployment, number of times deployed, rank and age were entered into a best subset logistic regression analysis for the best subset. Rank and history of injury were the best predictors of MSI and all assumptions were met, Table 16. As rank increased the risk of MSI decreased, OR=0.888, p=0.006. Those with a history of injury were at increased risk of MSI compared to those without a history, OR=4.326, p<0.001.

3.3 SPECIFIC AIM 3

Hypothesis 3: Of all the fitness and physical training variables, slower run times, higher weekly running mileage and less strength training will be positive predictors of MSI.

No fitness or physical training continuous variables were significantly correlated with MSI, Table 13. Push-ups, sit ups, and Army Physical Fitness Test scores all had p-values less than 0.1. Of the categorical variables, weekly frequency of unit runs, $\chi 2(2)=6.035$, $p=0.049$; and frequency of personal strength training, $\chi 2(2)=6.673$, $p=0.036$; were both significantly associated with MSI. No other categorical variables had p-values less than or equal to 0.1.

Relative risks were calculated for all fitness and physical training variables, Table 17. Women participating in no unit runs were at significantly greater risk than those participating in 1 to 3 unit runs per week, RR=1.526 CI 1.065-2.187. Women participating in personal strength training were at greater risk for MSI than those who were not, RR=1.42 CI=1.079-1.869. Women with Army Physical Fitness Test run times between 17 minutes and one second and 18 minutes were at greater risk for MSI than the fastest women who ran two miles in 17 minutes or less. Finally, all categories of Army Physical Fitness Test were at greater risk of MSI compared to women who score 290 and higher, Table 17.

Push-ups, sit ups, weekly frequency of unit runs, frequency of personal strength training, run time categories, and Army Physical Fitness Test categories were entered into the best subset analysis. Army Physical Fitness Test categories were used instead of continuous Army Physical Fitness Test because the RR was significant but the correlation was not. The best set of variables to predict MSI using logistic regression was categorical Army Physical Fitness Test, frequency of weekly unit runs, and frequency of weekly personal strength training and all assumptions were met, Table 18. Those scoring between 220 and 249 were at greater risk of MSI compared to those scoring 290 and above, OR=2.220, p=0.003. Those scoring between 250 and 289 were also at greater risk of MSI compared to those scoring 290 and above, OR=2.006, p=0.005. Those performing one to two unit runs per week were at less risk of MSI than those performing no unit runs per week, OR=0.411, p=0.001. Those performing one to two personal strength training sessions per week were at increased risk of MSI compared to those performing no personal strength training.

3.4 SPECIFIC AIM 4

Hypothesis 4: Of all the variables; rank, frequency of runs, and 2 mile run time will best predict MSI in female soldiers.

Brigade, history of deployment, number of times deployed, rank, age, history of injury, push-ups, sit ups, weekly frequency of unit runs, frequency of personal strength training, run time categories, and Army Physical Fitness Test categories were all entered into the best subset analysis. Rank, history of injury, weekly frequency of unit runs, and weekly frequency of personal strength training were the best model to predict MSI and all assumptions were met, Table 19. As rank increases risk decreases, OR=0.878, p=0.004. Those with a history of injury are at greater risk of MSI than those without a history of injury, OR=4.299, p<0.001. Those performing one to two unit runs per week were at less risk of injury compared to those performing no unit runs, OR=0.515, p=0.013. Those performing one to two sessions of personal strength training per week were at increased risk of injury compared to those performing no personal strength training, OR=1.793, p=0.008.

Table 6. Demographic and Body Composition Variables

Variable	Mean	Standard Deviation
Age	26.3 years	5.9
Height	1.64 m	3.0
Weight	66.18 kg	21.1
BMI	24.6 kg/m^2	3.3
Number of Injuries	2.04	1.5
Days on Profile	69.9	90.1
Variable	**Mode**	
Rank	E4	
Brigade	White	
Number of Times Deployed	1	
Previous Injury	No	

BMI – Body mass index

Table 7. Inclusion and Exclusion Criteria for Musculoskeletal Injuries

Question	Included	Excluded
Was the injury accidental or intentional?	Accidental	Intentional
What type of injury was it?	Sprains	Bruises
	Strains	Scrapes
	Dislocations	Cuts
	Fractures	Blisters
	Tendonitis	Concussions
	Nerve Injury	Amputations
	Pain	Burns
		Heat Injuries
		Cold Injuries
What was the cause of the injury?	Fall	Struck
	Trip	Cut
	Jump	Fire or Hot Substance
	Overexertion	Environmental Factors
	Repetitive Motion	Breathing or Swallowing Dust
	Other	

Table 8. Comparison of Demographics between the Two Definitions of Injury

Variable	**MSI**		**PHC Injury**	
	Mean	**SD**	**Mean**	**SD**
Age	25.46	5.04	25.95	5.76
Height	64.63	3.19	64.77	3.16
Weight	146.79	22.65	146.79	22.65
BMI	24.72	3.41	24.65	3.50
	Median	**Mode**	**Median**	**Mode**
Rank	E4	E4	E4	E4
Brigade	White	White	White	White
Previous Deployment	Yes	Yes	Yes	Yes
Number of Previous Deployments	1	1	1	1

BMI – Body mass index
MSI – current study injuries
PHC Injury – injuries according to the US Army Public Health Command definition of injury
SD – standard deviation

Table 9. Descriptive Statistics for the Sample

Variable	Mean	Standard Deviation
Age (years)	26.30	5.90
Height (cm)	164.08	7.62
Weight (kg)	65.95	9.57
BMI (kg/m2)	24.6	3.30
Unit Run (miles/week)	7.62	7.52
Personal Run (miles/week)	3.23	5.16
Run Total (miles/week)	10.8	9.82
Push Ups	40.00	12.87
Sit Ups	65.48	13.30
Run	17.53	2.08
APFT	248.89	36.41
Number of Injuries*	2.04	1.53
Days on Profile	69.90	90.07

BMI – Body mass index.
APFT – Army Physical Fitness Test
*Number of injuries using the broader Public Health Command definition

Table 10. Types of Injury

Type of Injury	N	Percent
Sprain	49	26.34
Strain	33	17.74
Dislocation	5	2.69
Fracture	8	4.30
Tendonitis/Bursitis	16	8.60
Nerve Injury	4	2.15
Pain	25	13.44
Other	46	24.73
Total	186	100

Table 11. Anatomical Body Region Injured

Body Part Injured	N	Percent
Head, Neck, Shoulder	11	5.91
Upper Back, Chest, Abdomen	5	2.69
Lower Back	14	7.53
Hip, Pelvis, Thigh	16	8.60
Knee	17	9.14
Lower leg	8	4.30
Ankle	24	12.90
Foot	7	3.76
Multiple parts	24	12.90
Missing	60	32.26
Total	186	100

Table 12. Activity Associated with Injury

Activity Associated	N	Percent
Running	63	33.87
Walking, Hiking, Marching	35	18.82
Lifting Heavy Objects	28	15.05
Stepping/Climbing	12	6.45
Sports	11	5.91
Other Exercise	10	5.38
Riding/Driving in a Vehicle	3	1.61
Other	15	8.06
Missing	9	4.84

Table 13. Point Bi-Serial Correlations of Continuous Variables to Injury

Variable	p-value	r
Rank	0.004	-0.12
Age	0.028	-0.09
Height	0.645	0.02
Weight	0.292	0.04
BMI	0.413	0.03
Unit Run Weekly Total Mileage	0.772	-0.01
Personal Run Weekly Total Mileage	0.465	-0.03
Total Run Weekly Mileage	0.534	-0.03
Push-Ups	0.059	-0.08
Sit Ups	0.078	-0.08
2-Mile Run Time	0.453	0.04
APFT Score	0.063	-0.08

BMI – Body mass index
APFT – Army Physical Fitness Test

Table 14. Associations between Categorical Variables and Injury

Variable	p-value	$\chi2$
Brigade	0.054	5.85
History of Deployment	0.045	4.03
Number of Times Deployed	0.067	5.40
Participation in Unit PT	0.619	0.25
Unit PT Weekly Frequency	0.615	0.97
Calisthenics Weekly Frequency	0.550	2.11
Strength Training Weekly Frequency	0.971	0.001
Agility Weekly Frequency	0.20	1.65
Sprint Training Weekly Frequency	0.904	0.20
Road Marches times/month	0.955	0.33
Distance of Road March	0.790	1.05
Weight of Rucksack	0.169	1.89
Weekly Frequency Unit Runs	0.049	6.04
Length of Unit Runs	0.221	3.02
Personal PT	0.517	0.42
Personal Strength Training Weekly Frequency	0.036	6.67
Personal Runs Weekly Frequency	0.877	0.26
Length of Personal Run	0.645	0.88
History of Injury	<0.001	63.78
Passed APFT	0.612	0.26

APFT – Army Physical Fitness Test

Table 15. Relative Risk for Demographic and Body Composition Variables

Variable	Injured	Uninjured	RR	95% CI
Rank				
E1-4	142	275	1.68	1.01-2.77
E5-9	30	107	1.08	0.60-1.92
OW	13	51	1	
Age				
≤25	109	234	1.43	0.99-2.08
26-30	50	108	1.42	0.95-2.14
≥31	26	91	1	
Height				
57 to 61	25	58	1.02	0.71-1.47
62 to 66	119	285	1	
67 to 79	40	93	1.02	0.76-1.38
Weight				
92-129	45	94	1.17	0.85-1.61
130-149	65	170	1	
150-169	45	113	1.03	0.75-1.42
170-244	29	56	1.12	0.75-1.64
BMI				
<25	100	246	1	
≥25	82	180	1.08	0.85-1.38
Brigade				
Red	47	149	1	
White	78	181	1.26	0.92-1.71
Blue	60	109	1.48	1.07-2.04
History of Deployment				
No	84	161	1.27	0.99-1.62
Yes	101	273	1	
Number of Times Deployed				
0	84	160	1.48	1.02-2.13
1	72	181	1.22	0.84-1.78
≥2	28	92	1	
History of Injury				
No	89	352	1	
Yes	96	87	2.60	2.06-3.28

E1-4 is private through specialist, E5-9 is sergeant through command sergeant major, OW is officer and warrant officer

Table 16. Logistic Regression for Demographic and Body Composition Variables

	B	**S.E.**	**Wald**	**df**	**p-value**	**OR**	**95% CI**	
							Lower	Upper
Rank	-0.12	0.04	7.67	1	0.006	0.89	0.82	0.97
History of Injury	1.47	0.19	58.46	1	<0.001	4.33	2.97	6.30
Constant	-0.79	0.23	12.33	1	<0.001	0.45		

Table 17. Relative Risk for Physical Training and Fitness Variables

Variable	Injured	Uninjured	RR	95% CI
Participated in Unit PT				
No	31	80	1	
Yes	153	354	1.08	0.78-1.50
Unit PT Times/Week				
0	29	79	1	
<5	39	82	1.20	0.80-1.80
≥5	114	270	1.11	0.72-1.57
Unit Calisthenics Times/Week				
0	47	117	1	
1 to 2	62	158	0.98	0.71-1.36
3 to 4	36	86	1.03	0.72-1.48
>4	37	66	1.25	0.88-1.79
Unit Agility Training Times/Week				
0.00	125	269	1.17	0.90-1.52
≥1	57	153	1	
Unit Strength Training Times/Week				
0	127	295	1.02	0.78-1.33
≥1	55	131	1	
Unit Sprint Training Times/Week				
0	58	141	1.00	0.67-1.50
1 to 2	101	229	1.05	0.72-1.54
≥3	23	56	1	
Unit Road Marches Times/Month				
0	57	129	1.09	0.74-1.60
1	58	131	1.091	0.74-1.60
2	27	69	1	
≥3	37	94	1.004	0.66-1.53
Average Distance of Road March				
0	54	127	1.09	0.80-1.47
1-3 miles	40	91	1.11	0.80-1.54
4-6 miles	66	174	1	
≥7 miles	17	32	1.26	0.82-1.95

Table 17. (continued)

Variable	Injured	Uninjured	RR	95% CI
Weight of Road March Pack				
0-30	65	176	1	
≥31 lbs	59	121	1.22	0.91-1.63
Unit Runs Times/Week				
0	65	126	1.526	1.07-2.19
1 to 2	33	115	1	
≥3	83	186	1.38	0.98-1.96
Average Length of Unit Run				
0	64	126	1.3	0.95-1.78
1 to 3	50	143	1	
≥4	65	150	1.17	0.85-1.60
Unit Run Weekly Mileage				
0	66	126	1.44	0.96-2.15
1 to 5	23	73	1	
6 to 10	27	73	1.13	0.70-1.82
>10	65	147	1.28	0.85-1.93
Participated in Personal PT				
No	38	100	1	
Yes	147	339	1.1	0.81-1.49
Personal Strength Training Times/Week				
0	68	209	1	
1 to 2	76	142	1.42	1.08-1.87
≥3	39	82	1.31	0.94-1.83
Person Run Times/Week				
0	91	207	1.09	0.82-1.44
1 to 2	57	146	1	
≥3	36	84	1.07	0.75-1.52
Average Personal Run Length				
0	84	182	1.2	0.80-1.81
1 to 3 miles	80	193	1.12	0.74-1.68
≥4 miles	21	59	1	

Table 17. (continued)

Variable	Injured	Uninjured	RR	95% CI
Personal Run Weekly Run Mileage				
0	94	213	1.07	0.80-1.44
1 to 5	46	115	1	
6 to 10	45	106	1.04	0.74-1.47
Weekly Run Total				
0	48	91	1.29	0.94-1.78
1 to 10	55	151	1	
11 to 20	56	119	1.2	0.88-1.64
>20	23	61	1.03	0.68-1.55
Push-Ups				
0 to 25	28	57	1.45	0.97-2.17
26 to 35	41	88	1.4	0.97-2.02
36 to 45	46	103	1.36	0.95-1.95
>45	42	143	1	
Sit Ups				
≤60	70	137	1.61	0.96-2.71
61 to 70	39	111	1.24	0.71-2.16
71 to 80	33	87	1.312	0.75-2.31
>80	13	49	1	
Run Time				
≤17.00	38	133	1	
17.01 to 18.0	33	54	1.71	1.07-2.73
>18.0	56	123	1.41	0.90-2.19
APFT				
<220	36	82	1.74	1.01-3.02
220-249	53	98	2.01	1.19-3.38
250-289	65	153	1.7	1.02-2.86
≥290	14	66	1	
Passed APFT				
No	17	35	1.12	0.74-1.69
Yes	150	364	1	

APFT-Army Physical Fitness Test

Table 18. Logistic Regression for Physical Training and Fitness Variables

	B	S.E.	Wald	df	p-value	OR	95% CI	
							Lower	Upper
Army Physical Fitness Test			10.71	3	0.01			
APFT <220 vs. ≥290	0.57	0.36	2.42	1	0.12	1.76	0.86	3.59
APFT 220-249 vs. ≥290	0.80	0.27	8.78	1	0.003	2.22	1.31	3.76
APFT 250-289 vs. ≥290	0.70	0.25	7.78	1	0.005	2.01	1.23	3.27
Weekly Frequency Unit Runs			10.41	2	0.005			
Unit Runs 1-2 vs. 0	-0.89	0.28	10.15	1	0.001	0.41	0.24	0.71
Unit Runs 3 or more vs. 0	-0.23	0.22	1.09	1	0.30	0.80	0.52	1.22
Weekly Frequency Personal Strength Training			8.79	2	0.01			
Per. Strength 1 to 2 vs. 0	0.64	0.22	8.26	1	0.004	1.89	1.23	2.93
Per. Strength 3 or more vs. 0	0.51	0.27	3.71	1	0.05	1.67	0.99	2.82
Constant	-1.42	0.28	25.33	1	0	0.24		

APFT –Army Physical Fitness Test

Table 19. Logistic Regression for All Variables

	B	S.E.	Wald	df	p-value	OR	95% CI	
							Lower	Upper
Rank	-0.13	0.05	8.53	1	0.004	0.88	0.80	0.96
History of Injury	1.46	0.20	54.03	1	<0.001	4.30	2.91	6.34
Weekly Frequency Unit Runs			6.18	2	0.05			
Unit Runs 1 to 2 vs. 0	-0.66	0.27	6.11	1	0.01	0.52	0.30	0.87
Unit Runs 3 or more vs. 0	-0.31	0.22	2.00	1	0.16	0.73	0.47	1.13
Weekly Frequency of Personal Strength Trn			7.20	2	0.03			
Per. Strength 1 to 2 vs. 0	0.58	0.22	7.07	1	0.01	1.79	1.17	2.76
Per. Strength 3 or more vs. 0	0.37	0.26	1.99	1	0.16	1.45	0.87	2.41
Constant	-0.74	0.28	7.22	1	0.01	0.48		

4.0 DISCUSSION

This was a retrospective study investigating MSI in the female soldiers in three brigades of the 4th Infantry Division. The cumulative incidence of MSI over a 12 month period was 30% or 29.76 MSI per 100 person-years. While younger age, history of deployment, a 2-mile run time of 17-18 minutes, and lower Army Physical Fitness Test score were all related to MSI the best predictors in multivariate analysis were lower rank, history of injury, no weekly unit runs, and 1-2 sessions of personal strength training per week.

The injury rate of 30% in the current study is lower than most previous US military studies with the same definition of injury which ranged from 41% to 64%.[18,20,43,44] While three of these studies were done during Basic Training, one study was done with operational soldiers at Fort Bragg.[20] This study had an injury rate of 51%. This study only included mechanics while the current study investigated a wide range of military occupational specialties found in the brigades. Different military occupational specialties have different occupational demands and there has been a change in Army doctrine for physical training between the time frames of the two studies.[69,83] The new Physical Readiness Training was introduced in 2010 and has been shown to lower injury rates in training environments.[84] It is possible that with the combination of different military occupational specialties and the change in Army physical training guidelines, that the injury incidence in women was reduced.

The severity of injury in this study was measured by the number of days of restricted duty. The average number of days of restricted duty per injury in the current study was 69.9. This is much higher than all previous studies. The following study investigated soldiers in operational units. The average musculoskeletal injury in male infantry soldiers was 16 days.[7] In surveyed deployed soldiers the average number of limited duty days per injury was six days.[25] In the records review by Rhon, 10% of the physical therapy patients received limitations to duty lasting an average of 18 days while deployed.[9] The average number of days of limited duty in female mechanics at Fort Bragg was 12.6.[20] In a third deployed study, each injury resulted in an average of 8.5 days of limited duty.[22] It is possible that the current study has a higher number of limited duty days because limited duty days was included in the definition of MSI while the other studies cited here did not include limitation to duty in their definition of injury. By including less severe injuries, those not resulting in limited duty, the other studies have a higher denominator when calculating the average number of days of limited per injury and this results in a lower average number of days. In a Basic Training study using the same definition of injury as the current study, the average number of days of limited duty for females was 9.6.[18] This number did not include the limited duty time of 108 females who did not finish Basic Training once they left the unit.[18] Their time of limited duty was terminated when they left instead of continuing to follow them for the total time of limited duty which resulted in a lower number of limited duty days. In a second Basic Training study the average number of limited duty days for females was 8.5.[44] Again, this would only include the subjects until they were removed from their Basic Training unit. Anyone with serious injuries would be removed from their unit until they healed. This would result in a lower average limited duty days because the total number of days was not used. The current study shows the importance of including these more severe injuries. Thirty percent of the women in this study were on limited duty for 19% of the year. This is 8.2% of the female solider available duty time in this unit.

The most frequently injured anatomical body region was the ankle, 13%, while only 7.5% of the injuries were to the low back. The low back has been the most frequently injured body region military wide and in deployed environments.[1,9,12,13,25,40,85,86] Despite this, it is not unheard of for the ankle to be the most frequently injured body region in training studies.[15,18,19,87] In the study by Jones et al[87], 11% of the injuries to male basic trainees were to the ankle and 6% to the low back while in Almedia et al[15], 34% of the injuries were to the ankle while only 10% were to the back, neck, or trunk in a combined population of male and female basic trainees. In O'Connor et al[19], 11% of the injuries were to the ankle while there were no injuries to the low back in women, in men 20% of the injuries were to the ankle while only 2% were to the low back. In female Air Force Academy cadets ankle injuries were also the most common at 12.5% with back, trunk, and neck at 10%.[17] Knapik et al[18] found that 20% of female basic trainees had ankle injuries while only 7% had low back injuries. In the mechanics, the only other operational unit study, women suffered more low back injuries,10%, than ankle injuries, 8%.[20] The training environment and the operational environment are clearly different, soldiers are working instead of training and physical training is not as structured in operational units. They may be more similar than the deployed environment and operational environment. In the six deployed studies, the low back was the most frequently injured in all studies. [9,12,13,25,40,86] With military operations currently conducted in many locations across the globe, soldiers are spending greater amounts of time living and working in austere and hostile environments. Over two million service members have deployed (living and working in combat zones such as Iraq or Afghanistan) in the last ten years for 6-15 months at a time, with 40% of service members deploying more than once.[88]

Deployed soldiers are exposed to multiple physical stressors including occupational activities such as lifting and carrying equipment, patrols wearing heavy loads, working in awkward positions, and convoy operations (driving or riding in vehicles for hours while wearing combat equipment). This could result in higher rates of low back pain than seen in the garrison studies. Additionally, soldiers perform less unit PT when deployed. They are more likely to work out on their own or not work out at all. The change in occupational demands and PT may result in a higher frequency of low back injuries than ankle injuries in deployed soldiers. The military wide data included the Air Force, Navy, and Marines as well as injuries in those returning from deployment.[1] The other branches have different occupational demands and conduct different PT than the Army and this may result in higher levels of low back injuries than ankle injuries. Finally, the operational unit study on mechanics at Fort Bragg included only one MOS as mentioned in the previous paragraph.[20] Based on our data and previous studies, it appears that the operational environment at Fort Carson is more similar to training environments than to deployed environments or other branches of the military as far as which body region is injured most frequently.

Younger age and lower rank were correlated with injury but only rank predicted injury in multivariate analysis. Previous military training studies have identified older age as a risk factor for injury.[18,89] However studies in Infantry soldiers and mixed sex groups of soldiers have found that injury risk increased as age decreased.[11,58] In training environments everyone regardless of age must perform the same tasks while in the operational environment those with older ages tend to be in more managerial position and may have less exposure to possible risk factors such as physical labor.[8]

In concordance with the current study, three previous findings showed that lower ranks suffered more injuries in military samples studied in the US. [23,58,65] The current study found as rank decreases one level, the risk of injury increases 14%. A possible explanation for this is that lower ranks tend to perform more physical labor while higher ranks serve as managers/supervisors and are less exposed to physical hazards. E5 (sergeant) and E6 (staff sergeant) rank were also shown to be a risk factor for injury in two deployed study with mixed sex samples.[22,25] In deployed environments higher ranks may be called upon to participate in physical labor as well as managerial duties whereas they spend most of their time performing solely managerial duties when in the US.[22] The lower physical occupational demands for higher ranks in garrison may lower their injury rate while occupational demands remain high for those with lower ranks.

In the current study, a history of deployment was not associated with MSI. Trainees do not have a history of deployment so this variable is not studied in training populations. The study on mechanics at Fort Bragg also did not investigate this variable. Prior deployment was found to be predictive of injury in a study on deployed soldiers, so that was at least their second deployment.[25] It is possible that some of those with no history of deployment had serious previous injuries that prevented deployment. This could have made them more susceptible to injury during the current study time period. Once included in multivariate analysis this variable was no longer predictive of injury in the current study. This variable needs to be further studied in the operational environment as the current study is the only one to investigate it.

A previous history of injury was both associated with MSI and was a multivariate predictor of MSI. A history of injury increased the risk of injury by 330%. This is supported by the following prior studies. Those with a previous low back injury were at three to six times greater risk of re-injury.[68] A history of ankle injury increased the risk of future ankle sprains.[90] Previous history of injury was also found to be a risk factor for stress fracture in Army recruits.[91] History of injury has been shown to be a risk factor for future injury in athletes.[92,93] Even returning to sports or work after an injury, the person may still have biomechanical effects from the injury even after pain has resolved. In a study that examined the residual effects of recent low back pain in college athletes, results indicated that athletes with resolved low back pain had significantly slower shuttle run times than the uninjured group.[94] A study completed by Seay et al indicated differences in pelvis-trunk coordination between symptomatic runners with and without a history of low back pain.[95] A group of participants who had recovered from low back pain and were running without pain demonstrated coordination patterns that resembled those of runners who were currently experiencing low back pain. Ankle instability and laxity can continue even a year after injury.[96] Prevention strategies should focus on identifying modifiable factors in those with a history of injury to prevent re-injury.

Running, a type of physical activity, was the most frequently self-reported activity associated with MSI. Additionally, participating in one to two unit runs reduced the risk of injury compared to participating in no unit runs, a slight increase in physical activity was protective but once runs were increased to three or more time a week it was neither protective nor harmful. This suggests a U relationship with the lowest risk at a mid-range of running or physical activity. It was surprising that greater running mileage was not associated with MSI in the current study. This was examined in training environments, more running mileage led to more injuries but not faster speeds (one event in the Army Physical Fitness Test).[60-62] Reducing the running mileage in training decreased the number of injuries in female soldiers by over 10% and stress fractures by 54% with no reduction in running speed.[60,97] A suggestion from these studies was to incorporate more agility training into physical training. In the current study there was no association between increased agility training and MSI. Agility training neither decreased nor increased the risk of MSI. It is possible that while increased running mileage in training is a risk factor for injury, it does not increase risk in operational Army units. A study done with Infantry trainees found that running four or more days a week actually reduced the risk of injury.[8] Weekly running mileage is more accurately recorded in training environments. It is possible that soldiers in the current study were not as accurate in their estimation of weekly running mileage. Reducing running mileage in operational units may not reduce MSI. It is also possible that running mileage had already been reduced in these units. The new Physical Readiness Training had already been introduced at this time as well as programs such as Cross Fit which both emphasis reduced running mileage. If these brigades had already reduced their running there might not be an effect seen. The current study collected running frequency and mileage as categorical data. This reduced the accuracy when adding unit and personal running mileage. It is possible that those with injuries reported that they were participating in no unit runs now (cross-sectional) instead of the average weekly frequency of unit runs before they became injured. This would result in a higher percentage of those injured responding zero weekly unit runs which would skew the results and could explain way zero weekly unit runs may have an artificially increased risk of injury compared to 1 to 2 times per week. Future studies should investigate running mileage as factor in regular Army units again using continuous variables and prospectively.

The current study offers novel information by investigating personal physical fitness training. This has been studied in only one previous study which looked at deployed soldiers only.[22] The current study found that those performing personal weight training one to two times a week were at 41% higher risk than those performing no personal weight training in univariate analysis. Personal weight training continued to be a predictor in multivariate analyses. This time there was an upside down U shaped relationship. Those performing one to two sessions a week were at increased risk of injury while those not performing any personal weight training or three or more sessions a week were neither protected nor harmed significantly. The other study investigating personal weight training was a retrospective study of soldiers deployed to Afghanistan for one year. Results indicated personal weight training, as opposed to group physical training or exercise in general, was the 8th most common cause of injury accounting for 5% of injuries.[22] The study investigated the length of each individual strength training session as opposed to the weekly frequency of personal strength training as was investigated in the current study. Longer strength training duration was not an injury risk factor in the multivariate logistic regression for deployed soldiers even though soldiers listed it as a common cause. It might be assumed that strength training would lower injury risk (physical activity), although studies have found that strength (fitness) has little association with injury risk.[18] Further analysis revealed that those with longer strength training durations had more physically demanding occupations than others.[22] We were unable to analyze occupational risk factors in the current study. It is possible that those performing more frequent weight training had more physically demanding occupations. It is also possible that those performing more personal weight training were not doing so correctly and became injured.

The findings in the relationship between the frequency of running and personal strength training and MSI support the argument that physical activity level is more important than fitness level in regards to MSI. In the current study, univariate analysis of the relative risk of the fitness measure 2-mile run time found that women with run times between 17 and 18 minutes were at increased risk of MSI compared to those running faster than 17 minutes. Two mile run time was not a predictor of MSI in multivariate analysis. This is contradictory to many findings in training studies. Slower run times on 1 mile, 1.5 mile and 2 mile runs were risk factors for injury in training both in univariate and multivariate analysis.[18,44,46,64] It is unusual that the middle category for run time was found to be at increased risk. In all previous studies the slowest soldiers have been at increased risk. In univariate analysis those running two miles in 17-18 minutes were at 70% higher risk of MSI than those running faster than 17 minutes. Since this variable was not a predictor in multivariate analysis it is possible that this finding is not of great importance when other variables are controlled for in analysis. More research needs to be conducted on operational units in order to assess if 2-mile run time is indeed a risk factor for MSI in soldiers.

Army Physical Fitness Test was a risk factor for MSI in both univariate and multivariate analysis of physical training and fitness variables but not the multivariate analysis including all variables. Those scoring 290 and above were at decreased risk of MSI compared to all others in univariate analysis and in multivariate analysis, only those score 220-289 were at increased risk compared to those scoring 290 and above. Total Army Physical Fitness Test score has been found to be a predictor of low back injury in soldiers but was not analyzed separately for each sex or for MSI in general.[49] This study followed soldiers for two years including both their occupational training and their first 18 months in an operational unit. In training studies, total Army Physical Fitness Test was not found to be a predictor for MSI. It is possible that total fitness, as measured by Army Physical Fitness Test, is more important for operational soldiers than just running fitness, as is the case in training environments. However, once rank and history of injury were added to the logistic equation, Army Physical Fitness Test was no longer a predictor of MSI suggesting that physical activity level is more important than fitness level in predicting MSI.

It is important to keep in mind that these results may not be generalizable to civilians. The Army population is much younger and more fit than the civilian population. It is also possible that the Army population is more resistant genetically to injury. Soldiers who receive long term injuries are often medically discharged from the Army leaving those who may naturally be less prone to injury to move on to higher ranks.

4.1 CONCLUSION

This study supports the argument that physical activity level is a better predictor of injury than fitness level. Running once or twice a week with the unit protected against MSI while participating in personal strength training sessions once or twice a week increased the risk of MSI. Both suggest U shape relationships between MSI and physical activity. Fitness was neither protective nor harmful when all other variables were accounted for in the equation. By focusing on physical activity, specifically unit running and personal strength training, the US could reduce the billions of dollars spent on training, healthcare, and disability costs.

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