United States Marine Corps
Ground Combat Element Integrated Task Force Research
ONR Award #N00014-14-1-0021

Final Report
August 14, 2015

NEUROMUSCULAR RESEARCH LABORATORY
DEPARTMENT OF SPORTS MEDICINE AND NUTRITION
UNIVERSITY OF PITTSBURGH

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EXECUTIVE SUMMARY MEMORANDUM 14 AUGUST 2015

University of Pittsburgh/United States Marine Corps Ground Combat Element Integrated Task Force Research

1. Research aims have enabled a thorough scientific approach to testing and analysis of tactical requirements and musculoskeletal and physiological profiles of Marines by identifying modifiable contributors to injury and optimal physical readiness, providing injury surveillance, and identifying and assessing tactical demands of male and female Marines during ground combat element training and operational assessments (ONR Award #N00014-14-1-0021).
2. Key Findings
   - 2.1. On average, male Marines performed significantly better than female Marines on strength, physiology, and field tests of power and agility; female Marines performed significantly better than male Marines on the majority of flexibility variables, balance, and biomechanical variables; male and female Marines performed comparably on the balance scores associated with the NeuroCom Sensory Organization Test (SOT) and Functional Movement Screen.
   - 2.2. When female Marines were assessed to determine the percent who met or exceeded the bottom 5th percentile male score, a proportion of female Marines met or exceeded the 5th percentile of male Marines for all variables; the lowest proportion was observed for absolute shoulder external rotation strength (7%), and the highest proportions were observed for the vestibular SOT score, sit and reach (flexibility), and fat mass (100%).
   - 2.3. Forty-three percent of male Marines and 46% of female Marines reported supplementation usage.
   - 2.4. Better aerobic and anaerobic capacity, ankle strength, and knee biomechanics were associated with MOS School graduation (significant point-biserial correlation, excluding motivational drops from analysis).
   - 2.5. Higher aerobic capacity and shoulder external rotation strength were associated with decreased odds of injury (Odds Ratio (OR) =0.999 and 0.987, respectfully; $p<0.05$) for all Marines during GCE ITF training and operational assessments; when just field tests were considered, longer standing broad jump was associated with decreased odds of injury (OR=0.982, $p=0.022$) (excluding motivational drops from analysis).
   - 2.6. During GCE ITF training and operational assessments, 40.5% of female Marines and 18.8% of male Marines reported at least one musculoskeletal injury; the highest percentage of injuries were located at the hip for female Marines and foot/toes for male Marines, respectively, and the highest percentage of injuries were attributed to ruck marching for both male and female Marines.
3. Current and Future Activities
   - 3.1. Continue analyses of data beyond final report to answer remaining research questions.
     - 3.1.1. Analysis of data relative to MCOTEA tactical outcomes, heart rate data, fatigue data.
     - 3.1.2. Further analyses of data collected as part of UPitt aims.
   - 3.2. Plan for and initiate longitudinal research aims, secure funding for continued execution of aims.
4. Longitudinal research aims (in support of MCFIO/OAD long-term integration research framework)
   - 4.1. Longitudinal surveillance and analysis of musculoskeletal injuries beyond the GCE ITF.
   - 4.2. Identify physical, physiological, musculoskeletal, and nutritional predictors of injury and optimal performance throughout a tactical lifespan.
   - 4.3. Develop intervention strategies to maximize resiliency and physical preparedness of Marines throughout tactical lifespan.
   - 4.4. Provide recommendations and/or additional research aims as needed/requested by Command.
5. POC for this memorandum is (b)(6) pitt.edu)

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Contents

Tables

Figures

University of Pittsburgh
United States Marine Corps
Ground Combat Element Integrated Task Force Research

Results Summary

Gender comparisons of male and female Marines were performed and demonstrated the following:

- On average, male Marines performed significantly better than female Marines on strength, physiology, and field tests of power and agility
- On average, female Marines performed significantly better than male Marines on the majority of flexibility variables, single-leg balance, and the majority of biomechanical variables
- Male and female Marines performed comparably on the balance scores associated with the NeuroCom Sensory Organization Test and had similar lactate threshold

Select variables were analyzed to determine percent of female Marines meeting or exceeding the bottom 5th percentile of male Marines (proportion overlapping the top 95% of male performers)

- A proportion of female Marines met or exceeded the 5th percentile of male Marines for all variables
- The lowest proportion (7%) of female Marines who met or exceeded the 5th percentile of male Marines was observed for absolute shoulder external rotation strength on the weaker side
- The highest proportion (100%) of female Marines who met or exceeded the 5th percentile of male Marines was observed for the vestibular score on the Sensory Organization Test, as well as for sit and reach (field flexibility test), and fat mass (where all female Marines met or exceeded the male standard)

Variables were assessed to identify changes between research stages

- For females graduating Entry Level Training (MOS School)
    - Trunk and ankle strength, balance, body composition, and upper body power significantly improved, while flexibility, hip and knee biomechanics, anaerobic power and capacity, and agility drill significantly worsened between pre-MOS school and baseline testing
- For male Marines
    - Knee and ankle strength, balance, knee biomechanics and landing forces, upper body power, aerobic capacity, and agility significantly improved, while torso rotation flexibility, anaerobic power and capacity, and body fat percent (circumference method) significantly worsened from baseline testing to interval testing
    - Ankle strength significantly improved, while shoulder, knee, trunk, and torso strength and anaerobic power significantly worsened from baseline to post-testing
- For female Marines
    - Ankle strength and Sensory Organization Test score significantly improved, while shoulder and trunk strength, torso rotation flexibility, balance, and anaerobic power significantly worsened from baseline to interval testing
    - Shoulder strength, Sensory Organization Test score, and fat free mass significantly improved, while knee and trunk strength, torso rotation flexibility, and hip biomechanics significantly worsened from baseline to post-testing

Nutrition profiles were developed for male and female Marines to optimize fueling patterns and behaviors relative to performance and health

- On average, female and male Marines reported under-fueling relative to reported energy expenditure
- Forty-three% of male Marines and 46% of female Marines reported supplementation usage

Analyses were conducted to determine predictors of female Marine graduation from MOS School

- Greater aerobic capacity, anaerobic capacity, ankle strength, and knee biomechanics were associated with MOS school graduation (when excluding motivational drops from analysis)

Analyses were conducted to determine predictors of incurring at least one Corpsman-reported injury during GCE ITF work-up training or operational assessment (motivational drops excluded)

When only demographic, UPitt field, and USMC PFT/CFT variables were considered:

- For all Marines combined, longer standing broad jump distance was associated with decreased odds of injury
- For male Marines, longer standing broad jump distance was associated with decreased odds of injury; for female Marines, no predictors emerged as significant

When all UPitt demographic, laboratory, field, and USMC PFT/CFT variables were considered:

- For all Marines, higher absolute VO2 Max and higher absolute shoulder external rotation strength on the weaker side were associated with decreased odds of injury, while higher absolute torso rotation strength on the weaker side was associated with increased odds of injury
- For male Marines, higher absolute shoulder external rotation strength on the weaker side, higher ankle inversion strength on the weaker side, and more favorable landing forces were associated with decreased odds of injury, while higher absolute torso rotation strength on the weaker side was associated with increased odds of injury
- For female Marines, higher lactate threshold was associated with increased odds of injury

Descriptive injury epidemiology was performed for male and female Marines

- 24.8% of Marines sustained at least one injury during GCE ITF work-up training and operational assessments (40.5% of female Marines and 18.8% of male Marines)
- For female Marines, the highest percent of injuries occurred at the hip and the highest percent of injuries were attributed to ruck marching
- For male Marines, the highest percent of injuries occurred at the foot and toes and the highest percent of injuries were attributed to ruck marching

Task and Demand Analyses were performed to determine musculoskeletal and physiological requirements in an operational environment

- Infantry and engineer MOS perform moderate- to long-duration loaded marches, traversing obstacles, and lifting heavy ammo/machinery/objects
    - Risk of upper and lower body strains from lifting and quick movements, and overuse injury from long duration loaded marches
    - Both anaerobic and aerobic energy system dependent, with focus on aerobic pathways for prolonged march under load
- Artillery and vehicle MOS perform primarily fast-paced, high intensity movements and lifting, requiring upper body and core strength for lifting heavy ammo/machinery/objects
    - Risk of upper extremity strains and overuse injuries
    - Anaerobic power and capacity primarily utilized, but aerobic capacity important for tasks that are repetitive in nature and that last longer than 10-20 minutes

Background
Rescinding the Direct Ground Combat Assignment Rule (DGCAR) on women serving in previously restricted occupations requires analysis of all Military Occupational Specialties (MOS) for task requirements. Such requirements will permit evaluation of current standards and validation of gender-neutral performance and training standards. These newly developed standards will ensure proper selection of personnel for the respective MOS based on the required skills and performance, regardless of gender.

Further research is needed to explore current fitness standards beyond initial fitness tests to determine the gender-neutral physical, physiological, and tactical requirements for the newly-opened MOS. Research also is necessary to assess if the physical readiness standards are adequate for the demands of each job and to determine the capability of female Marines to meet these demands and standards. Unlike athletics, gender-specific leagues do not exist in the military; female Marines must perform physical, occupational, and tactical tasks at the same level as their male counterparts.

Related Research
The University of Pittsburgh's Warrior Human Performance Research Model is dedicated to addressing the culturally-specific injury prevention and human performance needs of the tactical athlete. It originally was developed for the 101st Airborne Division (Air Assault) and born out of the University of Pittsburgh's successful research studying Anterior Cruciate Ligament (ACL) injuries in female athletes. The Warrior Human Performance Research Model uses an expanded public health approach to determine injury patterns, risk factors for injury, and effectiveness of intervention programs in this unique population of tactical athletes based on their occupational requirements.

The University of Pittsburgh's Neuromuscular Research Laboratory Female Athlete ACL Injury Prevention Project was designed to examine gender-specific physical and biomechanical characteristics contributing to higher risk of injuries in the female athlete[5, 6] and develop intervention strategies to alter injury mitigating characteristics. This line of research demonstrated that compared to male athletes, female athletes possessed significantly greater knee joint laxity,[7] decreased knee joint proprioception,[7] and decreased strength.[8] Females also demonstrated more dangerous landing mechanics compared to males, such as landing with significantly greater knee extension, less time to peak knee flexion, greater knee valgus, and greater electromyographic (EMG) activity of the hamstring muscles following landing a jump.[6, 7, 9-13] These results demonstrate that females may employ a compensatory muscle activation pattern to achieve joint stabilization, which is critical to force distribution mechanisms and reducing the risk of noncontact ACL injury. Based on these results a training intervention was developed to improve the specific injury-mitigating characteristics identified in female athletes and associated with ACL injury. The results of the study demonstrated significant improvements in strength, landing mechanics, and EMG activity.[14]

Expanded from the original human performance research with the 101st Airborne Division (Air Assault), the University of Pittsburgh's research has continued to address the culturally-specific and unique attributes of the Special Operations Forces community. With individual projects at Naval Special Warfare, US Army Special Operations Command, Air Force Special Operations Command, and Marine Corps Forces Special Operations Command, the University of Pittsburgh is positioned to scientifically evaluate the physical requirements, standards, and testing of integrating females into the restricted MOS.

The collected data have suggested there are several suboptimal biomechanical, musculoskeletal, physiological, and nutritional characteristics that are detrimental to injury potential, tactical operations, and physical readiness:

- Significant suboptimal scores in these characteristics exist in subsets of units[26-34] and related to prior injury history[35-37]
- Significant bilateral asymmetry exists across a wide range of strength, flexibility, balance, and biomechanical variables[25]
- Landing in positions of mechanical inefficiency during tactical activities which can be further impacted by carrying external loads[20]
- Higher than desirable body fat related to less than capable anaerobic and aerobic efficiency[21]
- Body fat results appear to be associated with less than desirable nutrient distribution in the diet for highly physically active persons[21-24]
- Insufficient and inappropriate macronutrient distribution diet and high supplement usage[21-24]

Based on the findings of our research, separate interventions were developed and tested in laboratory and field settings to modify injury mitigating characteristics, optimize physical readiness, and reduce preventable musculoskeletal injuries:

- Demonstrated improvements in musculoskeletal and physiological characteristics necessary for physical readiness, improving athleticism, and reducing the likelihood of musculoskeletal injury[38-40]
- Demonstrated improvements in performance and tactically-specific testing
- Demonstrated significant reduction in proportion of subjects sustaining musculoskeletal injuries, including overuse injuries and injuries to the upper extremity, lower extremity, knee, and lumbopelvic regions[41]
- Developed Instructor Certification School (ICS) for tactical personnel to implement validated intervention[40]

Additionally, our data from the 101st Airborne Division (Air Assault) demonstrated significant physical and physiological differences between male and female Soldiers and increased injury rates in female Soldiers.[26, 27]

- Female Soldiers have significantly higher body fat percentage and lower lean mass
- Female Soldiers have significantly lower anaerobic power and capacity, in both absolute terms and when normalized to body weight
- Female Soldiers have significantly lower aerobic capacity, in both absolute terms and when normalized to body weight
- Female Soldiers have significantly lower shoulder, knee, torso, and ankle strength, in both absolute terms and when normalized to body weight

The research model is culturally-driven based on the tactically-specific requirements of the unit. This project evaluated the physical and physiological requirements of female Marines in the context of successfully and safely performing the previously restricted MOS under the DGCAR and physical fitness testing and standards.

Scope of Work

The following research aims are in response to the United States Marine Corps' (USMC) request of the University of Pittsburgh to support its Integrated Task Force (ITF) and to provide immediate testing of the newly created integrated infantry unit. This research was designed to complement the ongoing activities of the ITF and is consistent with the University of Pittsburgh's Human Performance Research Model. A multi-aim approach was implemented to meet objectives and provide the deliverables necessary for the ITF to meet its established deadline for recommendations to the USMC Commandant.

Research aims:

- To perform an epidemiological analysis of injuries sustained by female and male Marines during MOS School, ITF unit integration, and at identified intervals following the decision/recommendation to integrate females into previously restricted MOS.
- To study the physical, physiological and nutritional demands of Marine Corps tactical and physical training during Task and Demand analyses and describe the gender-neutral requirements to perform such tasks relative to current Marine Corps physical fitness testing and passing standards
- To identify baseline modifiable biomechanical, physiological, and musculoskeletal characteristics (system level measurements) in female and male Marines during laboratory, performance, USMC Physical Fitness Test (PFT)/Combat Fitness Test (CFT) protocols and correlate with MOS School and ITF unit integration outcomes, and musculoskeletal injuries
- To initiate interval testing of laboratory, performance, and PFT/CFT protocols to assess the cumulative effects of MOS School, unit integration, and active duty to predict performance, attrition, and injury across the tactical life span.

Specific Aim 1 - Determine Physiological Predictors of Ground Combat Success
Provide recommendations on test protocol to determine predictors of MOS School and ITF unit integration outcome and Implementation of University of Pittsburgh Human Performance Research Model

Methodology: Assess musculoskeletal and physiological (laboratory and field based) screening characteristics to determine predictors of GCE MOS unit integration outcomes. Outcomes of success as part of Aim 1 were defined as resiliency related (i.e. injury/attrition status and changes over time). Tactical success is addressed as part of Aim 3, or the Task and Demand analysis.

Goal: Baseline test at least 200 female and male Marines prior to MOS school and/or GCE ITF integration and test at least 50 representative female and male Marines during interval and post-GCE ITF integration.

The following variables were selected according these criteria:

1. The variable is a known predictor of performance and physical readiness
2. The variable is an assumed or demonstrated risk factor for high incidence of injury
3. The variable may be compromised due to an injury and may need to be considered for rehabilitation/restoration

Laboratory Variable	Methodology	Field Variable	Methodology
Injuries/Nutrition	UPitt-Military Epidemiology Database (MED)	**Anthropometrics**	Height, Weight, Arm Span, Leg Length
Body Composition	Bod Pod Body Composition System	**Body Composition**	Circumference Taping
Aerobic Capacity/Lactate Threshold	Maximal Oxygen Uptake	**Upper Extremity Anaerobic Power**	Medicine Ball Toss
Anaerobic Power/Capacity	Wingate 30-second Cycle Sprint	**Lower Extremity Anaerobic Power**	Standing Broad Jump
Strength	Biodex Isokinetic Dynamometer (shoulder, knee torso); HHD (ankls)	**Posture**	Functional Movement Screen
Biomechanics	Kinetic and Kinematic Analysis of Tactical Movements	**Flexibility**	Sit and Reach Test
Flexibility	Inclinometer/Goniometer (ROM of major joints)	**Agility**	Pro-Agility (5-10-5) drill
Balance	Static and Dynamic Balance (force plate); NeuroCom Sensory Organization Test (SOT)	**Aerobic Capacity**	3 mile run for time (PFT)
		UE Strength	Pull-ups/Flexed Arm Hang (PFT)
		Core Strength	Sit-ups (PFT)
		Anaerobic Capacity	Movement to Contact; Maneuver under fire (CFT)
		UE Muscular Endurance	Ammo lift (CFT)

Summary – UPitt Laboratory and Field Variables

Male and female Marines who were enrolled as part of the GCE ITF were recruited to participate in the University of Pittsburgh arm of the research study. Subjects were recruited during group briefs and were eligible to participate if they met the following inclusion criteria: 1) Male or female Marines aged 18-55 years; 2) No injury to muscle or bone within the previous 3 months; and 3) No allergy to adhesive materials; 4) No concussion or mild head injury within the past year; 5) No history of neurological or balance disorders. Male and female Marines attending the recruiting brief were provided an overview of the study aims and were permitted to ask any questions prior to scheduling a testing session. All subjects understood and signed an informed consent document prior to undergoing any testing procedures.

A sub-set of female Marines were tested prior to attending GCE MOS School. During the Pre-MOS school phase of testing, 68 female Marine volunteers were tested (Table 1). Forty-one female Marines retested as part of the Marines tested during the baseline, Pre- GCE ITF phase.

Pre-GCE ITF (baseline) testing began as volunteers checked into Camp Lejeune beginning in mid-August 2014. The breakdown of subjects by MOS and gender are presented in Table 2. Demographic information for this group is as follows: combined (age: 22.5 ± 2.7 years, height: 68.2 ± 3.4 in, weight: 76.1 ± 12.2 kg), females (age: 22.6 ± 2.8 years, height: 64.5 ± 2.3 in, weight: 64.3 ± 7.1 kg), and males (age: 22.4 ± 2.6 years, height: 69.7 ± 2.6 in, weight: 80.7 ± 10.6 kg).

A subset of volunteers, primarily those tested in September and October, 2014 were re-tested during the Interval testing phase. The breakdown of subjects by MOS and gender are presented in Table 3.

A subset of volunteers who completed the entire GCE ITF work-up and experimental phase were re-tested during the Post-Test phase. The breakdown of subjects by MOS and gender are presented in Table 4.

Gender comparisons of male and female Marines were performed and demonstrated the following:

- On average, male Marines performed significantly better than female Marines on strength, physiology, and field tests of power and agility
- On average, female Marines performed significantly better than male Marines on the majority of flexibility variables, balance, and the majority of biomechanical variables
- Male and female Marines performed comparably on the balance scores associated with the NeuroCom Sensory Organization Test and had similar lactate threshold

Selected physiology, strength, NeuroCom Sensory Organization Test, and field variables were included in an analysis to calculate the proportion of female Marines who perform as good as or better than the male 5th percentile value for these variables. The results of this analysis are displayed in Table 5. For variables where a lower value is interpreted as better performance (Table 6), the proportions of female subjects who are at or below the male 95th percentile value were calculated. Ninety-fifth percent confidence intervals for the proportions were also calculated, and are presented in the tables.

The results of the analysis showed that the proportion of female Marines who met or were better than the standards as presented in Table 5 and Table 6, varied, depending on the variable under consideration. Among the variables analyzed, the lowest proportion of female Marines who met or were better than the standard was observed for absolute shoulder external rotation strength on the weaker side (6/83 = 0.0723), and the highest proportion was observed for the vestibular score on the Sensory Organization Test (SOT) (83/83 = 1.0000), sit and reach (field flexibility test) (84/84 = 1.0000), and fat mass (kg) (84/84 = 1.0000). For both the vestibular score on the SOT and sit and reach, all females were at or exceeded the male 5th percentile value for the corresponding variable. For fat mass (kg) all females were at or below the male 95th percentile value.

The following pages describe the specific methodologies utilized and the results of the baseline (Pre-ITF) research stage relative to gender and MOS group. Data also were compared between research stages in order to examine changes in these characteristics over time throughout GCE ITF training and operational assessment.

Laboratory Strength Variables

Shoulder Internal Rotation (IR) and External Rotation (ER) Strength

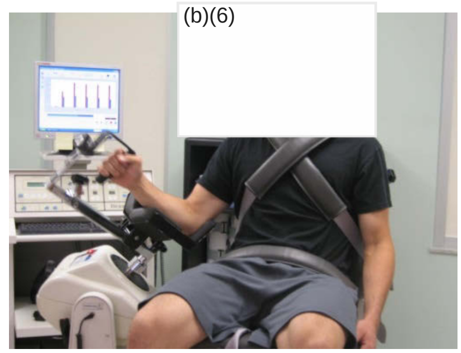

Figure 1. Isokinetic Shoulder Internal/External Rotation Testing

Background: Proper rotator cuff strength (internal and external rotation) is critical for the performance of demanding overhead tasks and maneuvers involving the upper extremity. The shoulder joint is dependent upon the health of the rotator cuff as a source of dynamic stabilization for the joint. Deficiencies in strength or reciprocal balance of the rotator cuff musculature may predispose the shoulder to altered joint kinematics leading to potential trauma, including acute and/or chronic instability and impingement syndromes.

Purpose: Examine rotator cuff strength

Testing methodology: Biodex System 3 isokinetic dynamometer (Biodex Medical, Shirley, NY); 5 repetitions; Isokinetic: 60°/sec; Average peak torque (N*m)

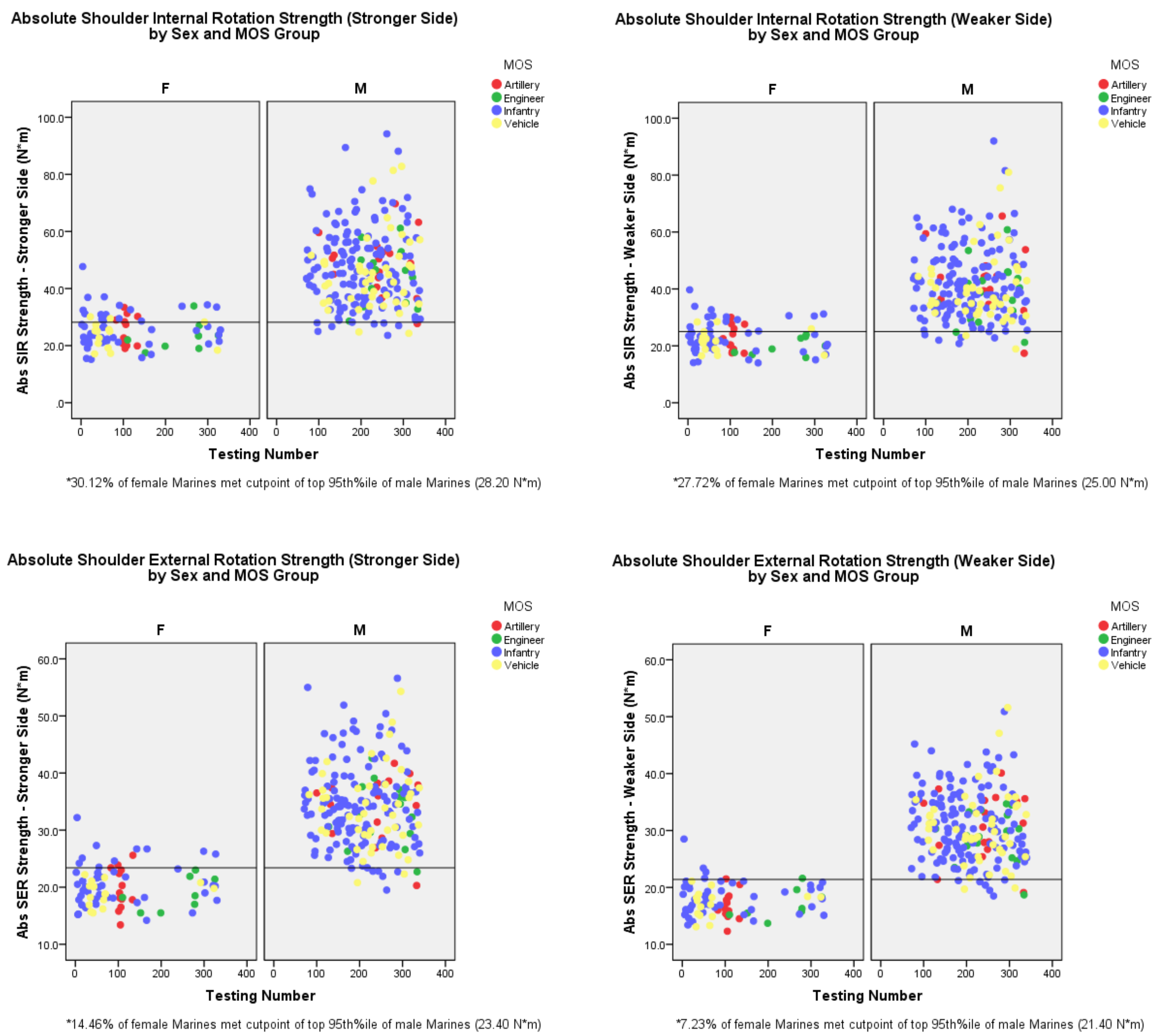

Figure 2. Shoulder Strength Scatterplots by Sex and MOS Group

<u>Knee Flexion (KF) and Knee Extension (KE) Strength</u>

Figure 3. Isokinetic Knee Flexion/Extension Testing

Background: Adequate strength of the hamstring and quadriceps muscle groups is vital for the performance of landing tasks and maneuvers associated with tactical operations training. These muscle groups contribute to the dissipation of imposed forces and stabilization of the knee joint during demanding lower extremity activities. Maintenance of appropriate strength ratios between the hamstring and quadriceps muscle groups may minimize the risk factors associated with traumatic and overuse knee and leg injuries during training.

Purpose: Examine knee flexion and extension strength
Testing methodology:
Biodex System 3 isokinetic dynamometer (Biodex Medical, Shirley, NY)
5 repetitions; Isokinetic: 60°/sec; Average peak torque (N*m)

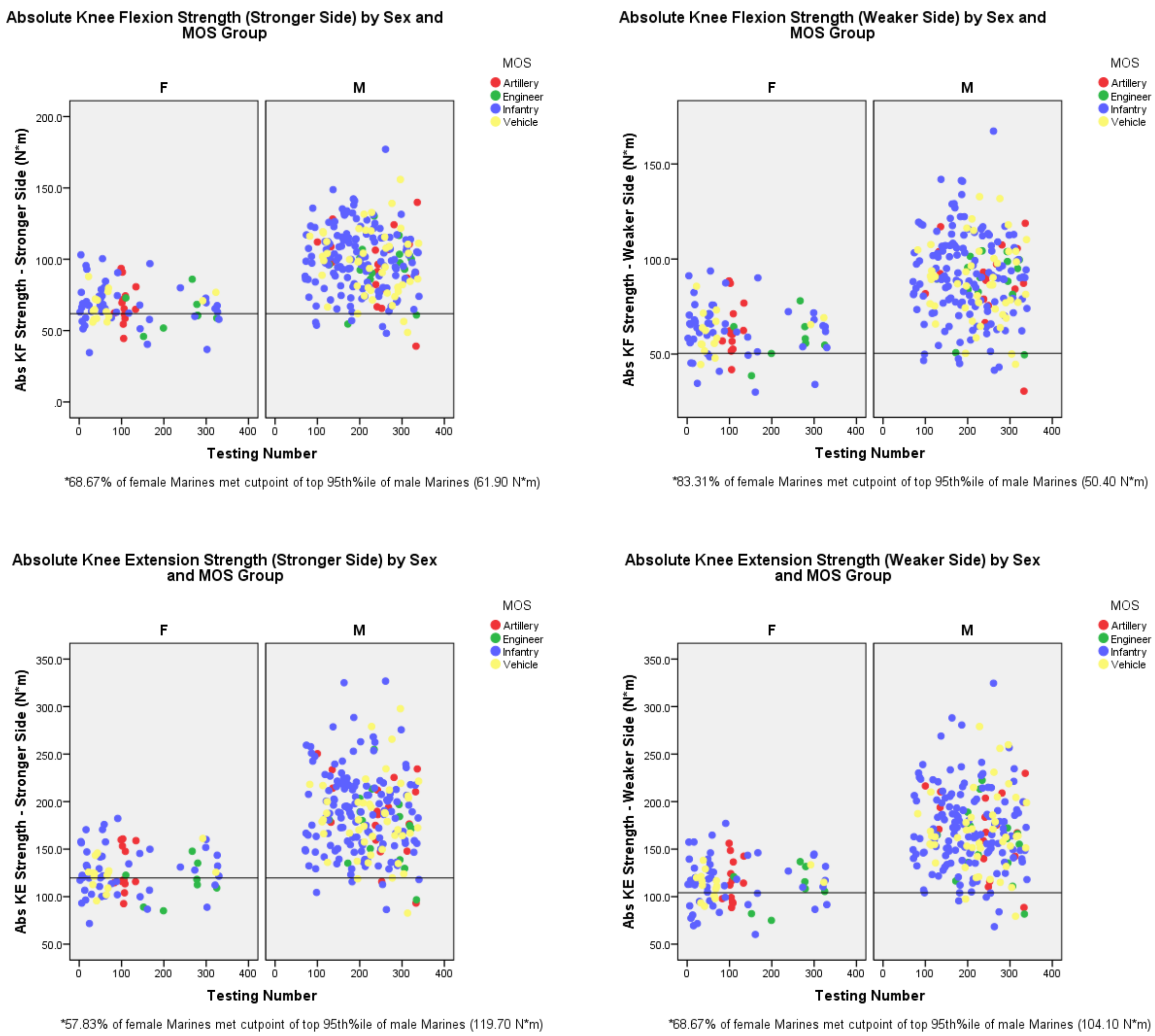

Figure 4. Knee Strength Scatterplots by Sex and MOS Group

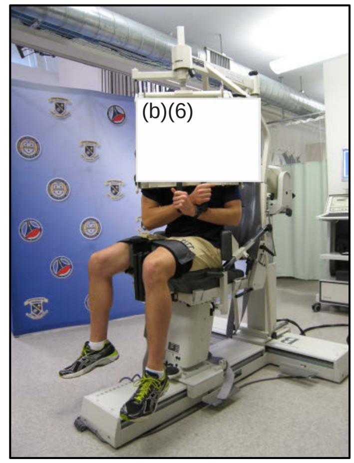

Figure 5. Isokinetic Torso Rotation Strength Testing

<u>Torso Right and Left Rotation and Trunk Extension/Flexion Strength</u>

Background: Adequate core strength is the pillar of maximal physical performance and contributes significantly to upper and lower extremity mobility and strength. Improving torso and trunk strength may have a positive impact on virtually every other performance variable and decrease the risk of injury as a result of enhanced musculoskeletal and cardiorespiratory efficiency.

Purpose: Examine right and left torso rotation strength and trunk extension/flexion strength

Testing methodology:
Biodex System 3 isokinetic dynamometer (Biodex Medical, Shirley, NY)
5 repetitions; Isokinetic: 60°/sec; Average peak torque (N*m)

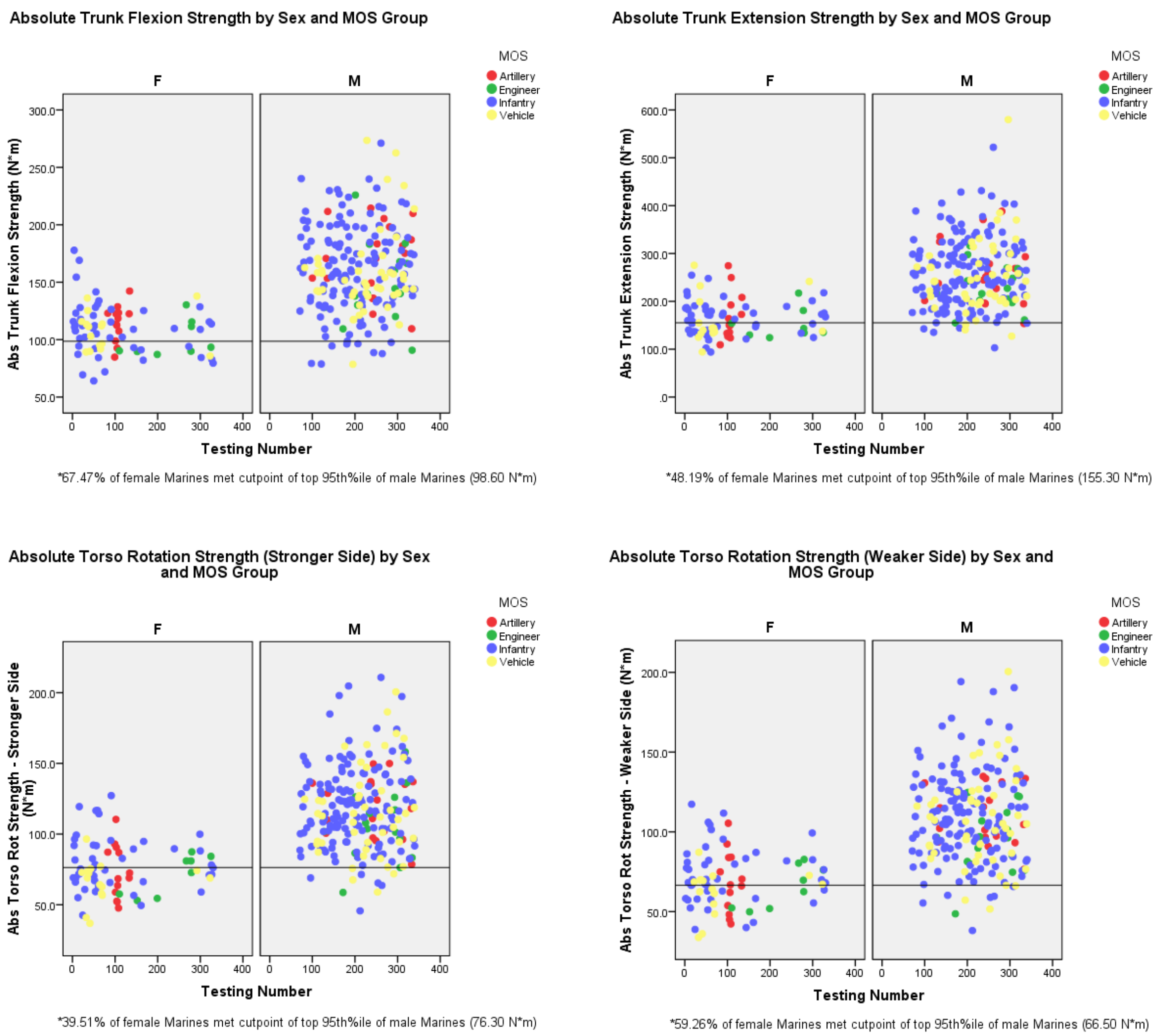

Figure 6. Trunk and Torso Strength Scatterplots by Sex and MOS Group

Ankle Inversion/Eversion Strength

Figure 7. Ankle Eversion Strength Testing

Background: Strong and balanced ankle musculature is important in creating and maintaining a solid base of support for the body. Optimal ankle invertor and evertor performance is vital in preventing the knee and ankle joints from developing altered kinematics, which can lead to knee overuse injury and/or ligament sprains, ankle sprains, as well as lower limb muscle strains and tendonopathies. Moreover, deficiencies in ankle muscle strength may predispose an individual to acute ankle injuries. Acute ankle injuries are notorious for spiraling into debilitating reoccurring and/or chronic injuries that are more difficult to treat and can greatly hinder athletic performance.

Purpose: Examine ankle inversion/eversion strength

Testing methodology:
Handheld Dynamometer (Lafayette Instrument Co., Lafayette, IN)
Ankle Inversion/Eversion: 3 repetitions; Isometric: Break Test; Peak Force (kg)

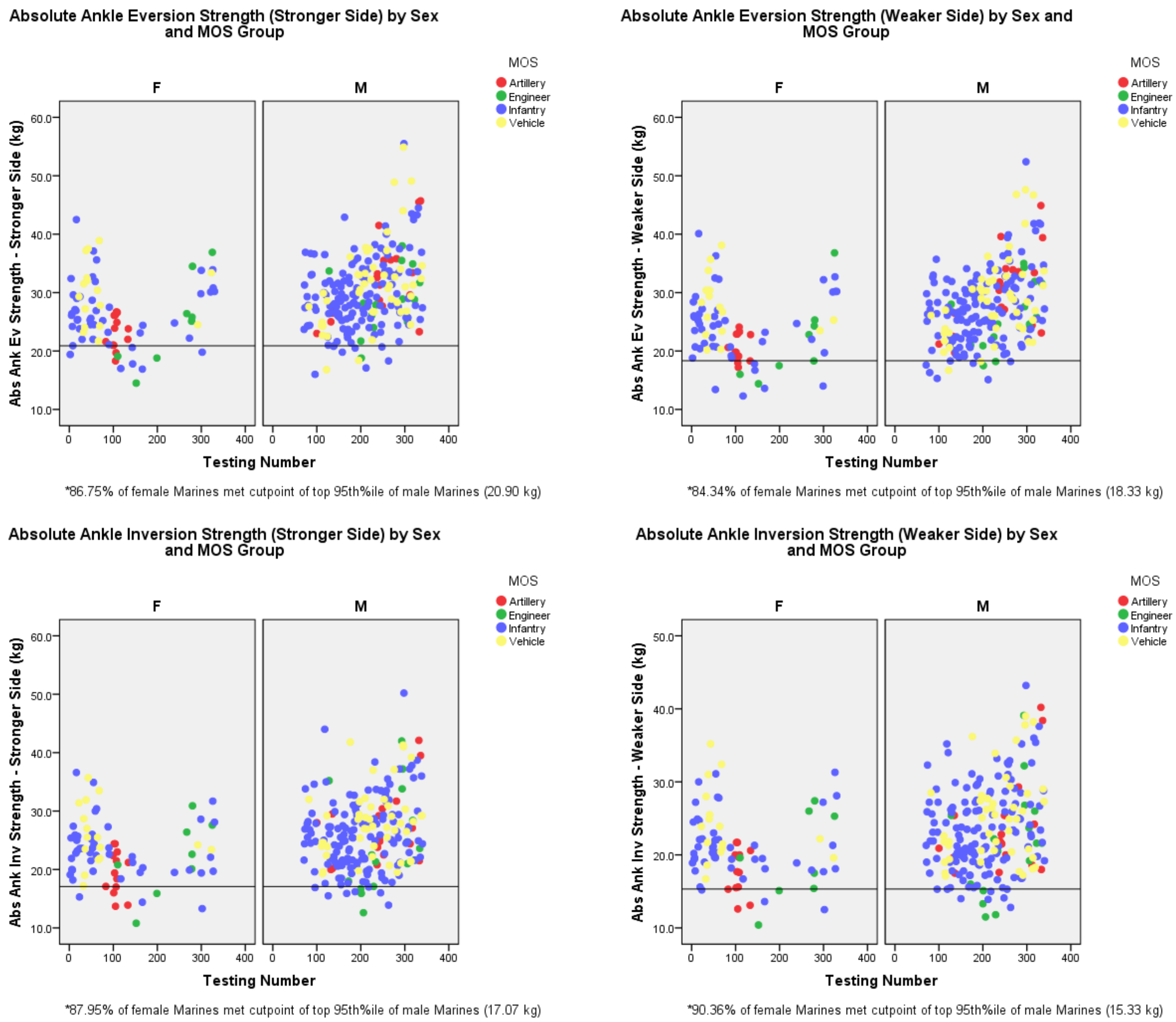

Figure 8. Scatterplots of Ankle Strength by Sex and MOS Group

Laboratory Flexibility Variables

Shoulder External Rotation, Internal Rotation, and Posterior Shoulder Tightness Flexibility

Background: Shoulder range of motion (ROM) is critical for maintenance of proper glenohumeral and shoulder girdle kinematics. A deficit in shoulder ROM may significantly impact overall performance during demanding overhead and upper extremity tasks and predispose to potentially traumatic and/or chronic pathologies. A balance between internal and external rotation flexibility is desired to maintain appropriate glenohumeral joint kinematics and contributes to better physical performance during overhead activities. Posterior shoulder tightness may be the result of inflexible rotator cuff muscles and/or tightening of the posterior joint capsule, which may lead to glenohumeral joint dysfunction and impingement syndromes.

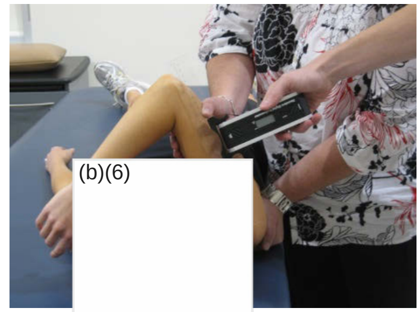

Figure 9. Posterior Shoulder Capsule Tightness Flexibility Testing

Purpose: Examine shoulder external and internal rotation and posterior shoulder tightness (PST) flexibility

Testing methodology:
Digital inclinometer
Average of 3 measurements (°)

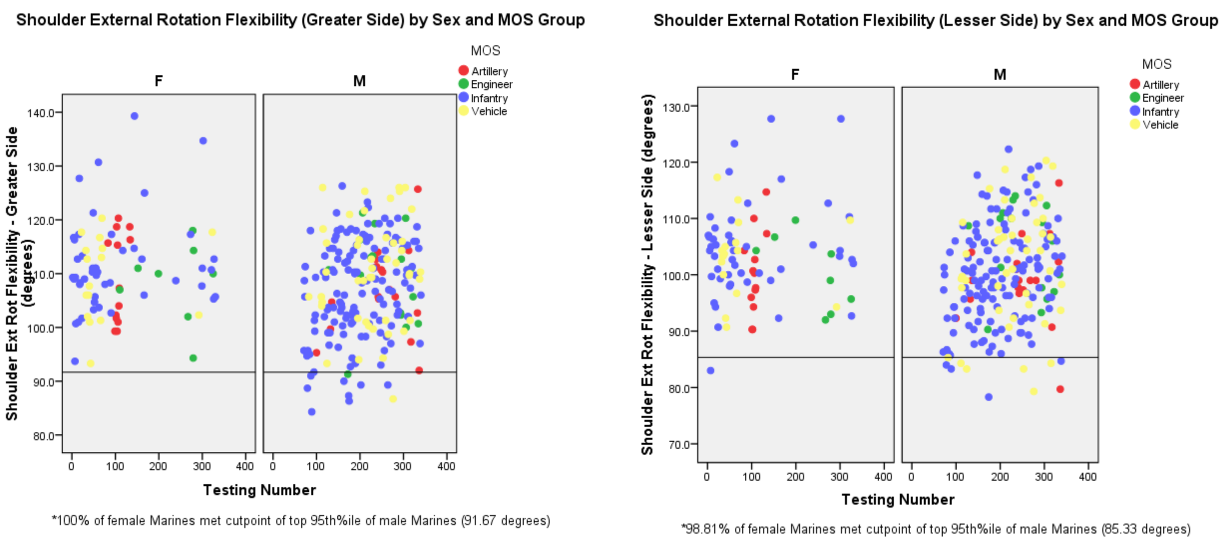

Figure 10. Scatterplots of Shoulder External Rotation Flexibility by Sex and MOS Group

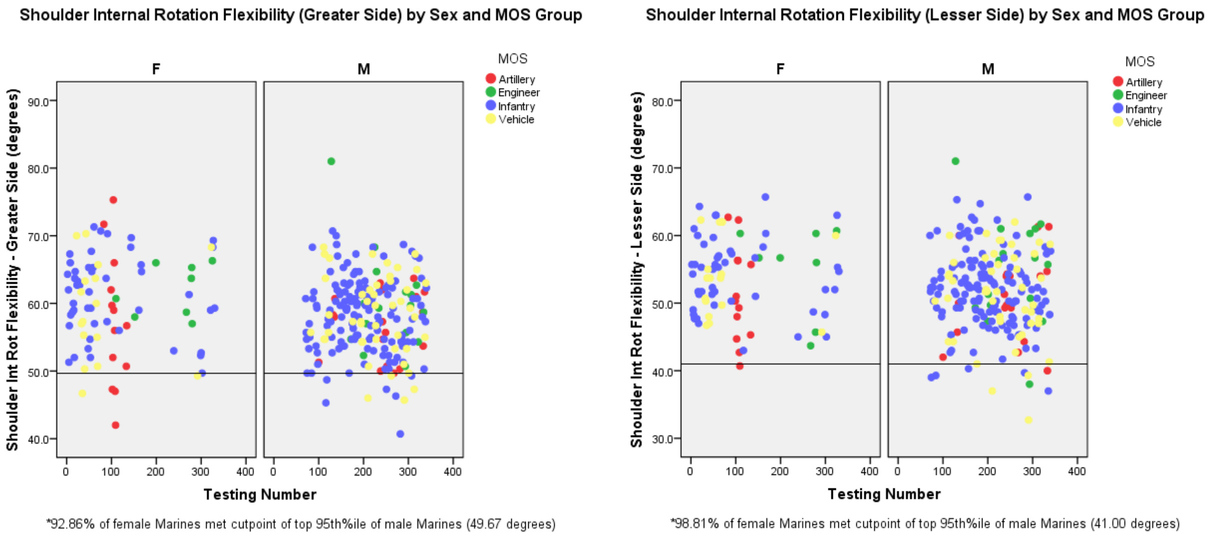

Figure 11. Scatterplots of Shoulder Internal Rotation Flexibility by Sex and MOS Group

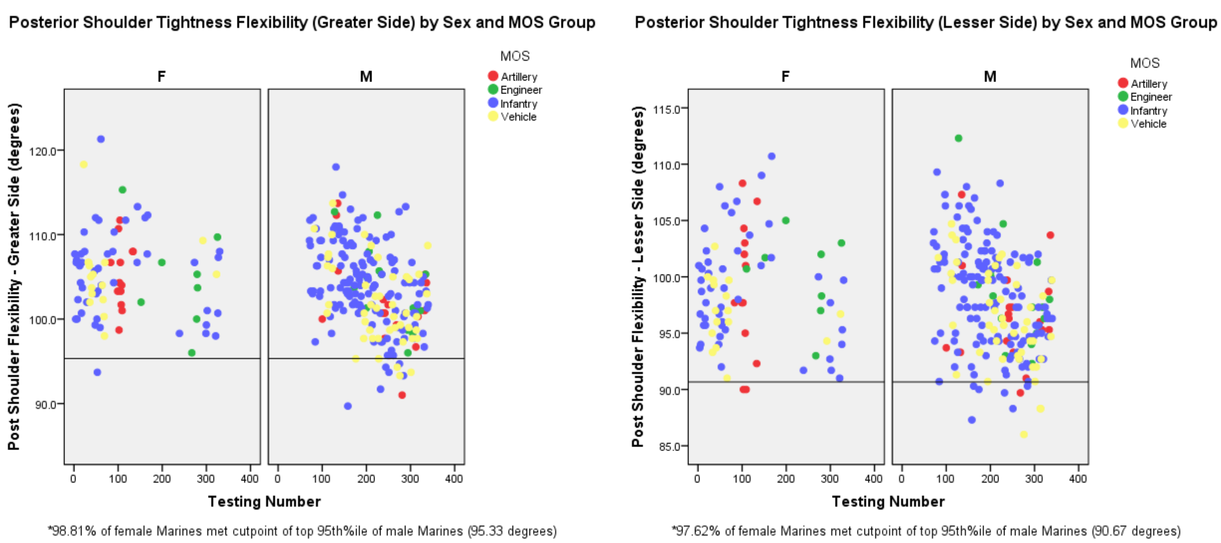

Figure 12. Scatterplots of Posterior Shoulder Tightness Flexibility by Sex and MOS Group

Torso Rotation Flexibility

Background: Adequate torso rotation flexibility is important for core stabilization and the generation of forces necessary to respond to demanding physical tasks. Deficits contribute to altered spinal mobility that may lead to injury to the lumbar spine and a decrease in efficiency of physical tasks involving the upper and lower extremities.

Purpose: Examine torso rotation flexibility

Testing methodology:
Biodex System 3 isokinetic dynamometer (Biodex Medical, Shirley, NY)
3 repetitions to right and left maximum rotation
Average of 3 joint angles (°)

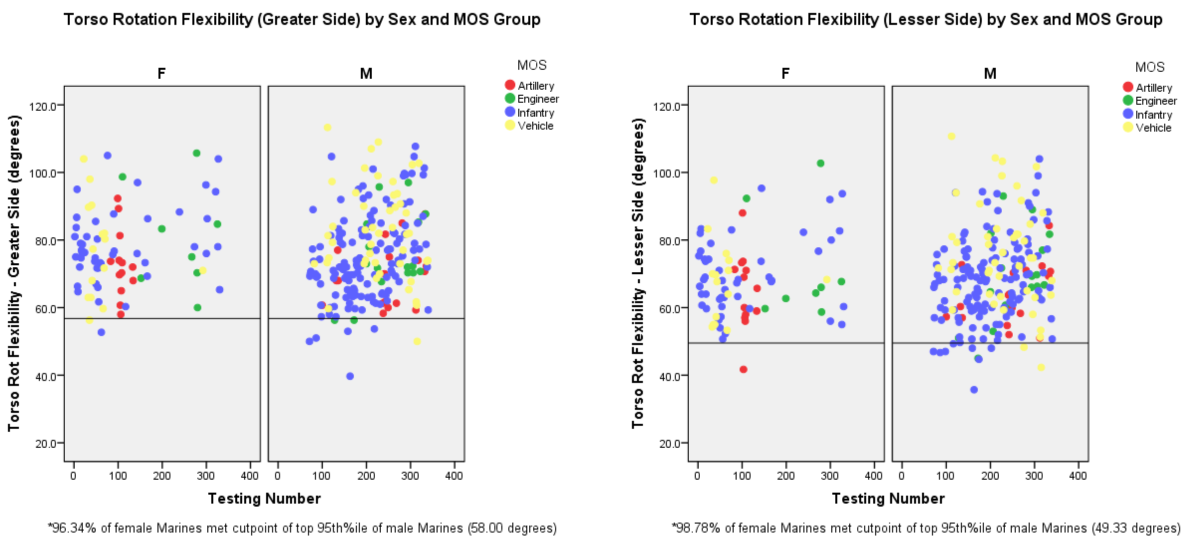

Figure 13. Scatterplots of Torso Rotation Flexibility by Sex and MOS Group

Hamstring Flexibility

Background: Maintenance of appropriate flexibility of the hamstring muscle group is important for allowing proper knee position during movement of the lower extremity, thereby minimizing risk of low back and lower extremity injury. Deficits in flexibility of these muscles may contribute to acute or chronic injuries affecting the proper functioning of the knee as well as the back and lower extremity.

Purpose: Examine hamstring flexibility (higher number indicates less flexibility, or increase bend during active knee extension)

Testing methodology:
Saunders Digital Inclinometer (The Saunders Group, Chaska, MN)
3 measures
Passive knee flexion and hamstring
Average of 3 joint angles (°)

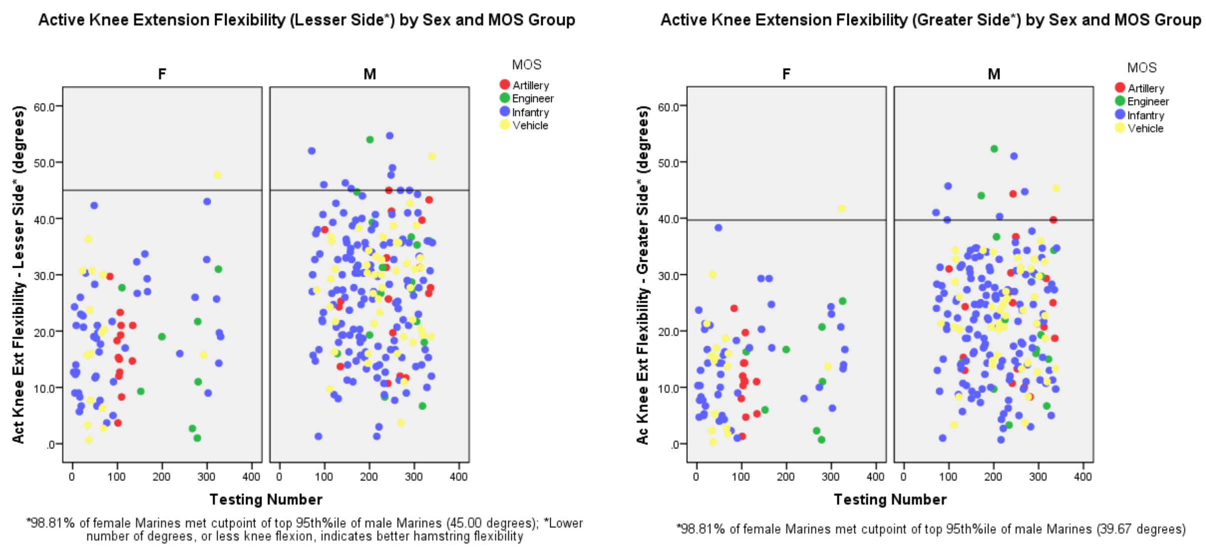

Figure 14. Scatterplots of Hamstring Flexibility by Sex and MOS Group

Ankle Flexibility

Figure 15. Ankle Dorsiflexion Flexibility Testing

Background: Adequate flexibility of the calf musculature contributes to proper mechanical functioning of the knee and ankle joints as well as the generation of forces necessary for tasks such as running and jumping. Deficits in calf musculature flexibility may have a negative impact on overall physical performance and may contribute to acute and/or chronic injuries involving the knee and ankle.

Purpose: Examine ankle dorsiflexion flexibility

Testing methodology:
Standard Goniometer
3 measures
Active ankle dorsiflexion
Average of 3 joint angles (°)

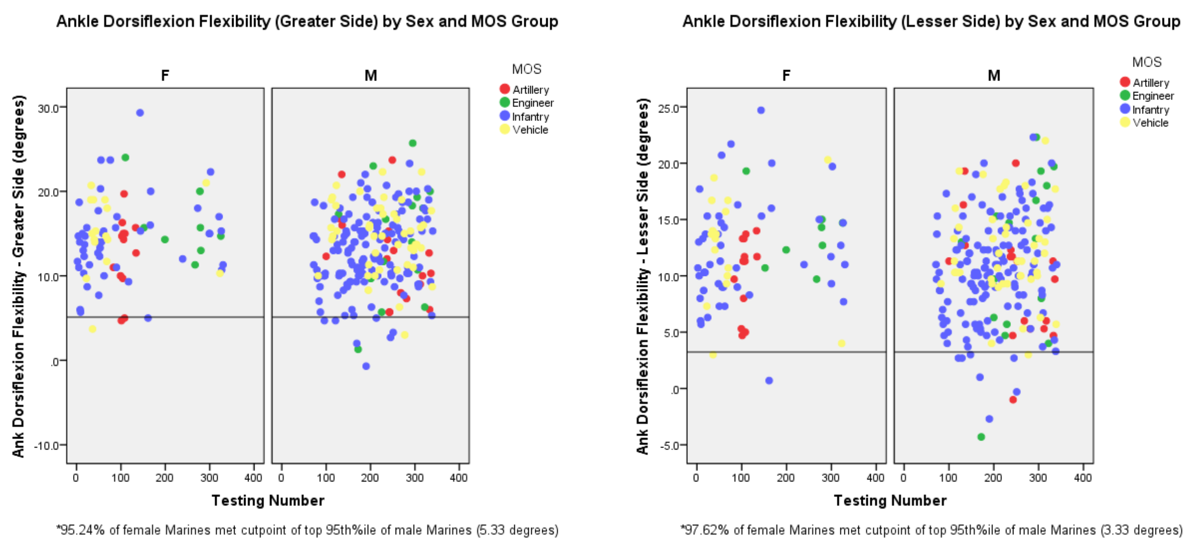

Figure 16. Scatterplots of Ankle Dorsiflexion Flexibility by Sex and MOS Group

Laboratory Balance Variables

Balance: Variability of Ground Reaction Forces (GRF)

Background: Accurate sensory information, as measured through single-leg balance testing, is essential to the performance of complex motor patterns, maintaining joint stability, and preventing injury. Deficits in this area may indicate a greater risk for ankle and knee injury.

Purpose: Examine static and postural stability through single-leg balance (lower values are indicative of better balance)

Testing methodology:
Kistler force plate
3 measures of movement variability
Average of 3 trials
Eyes open and eyes closed conditions

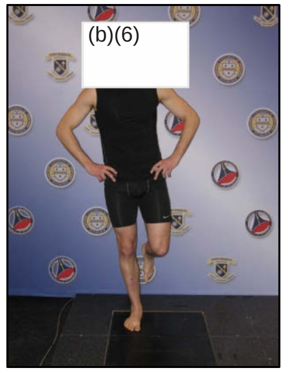

Figure 17. Single-Leg Balance Testing

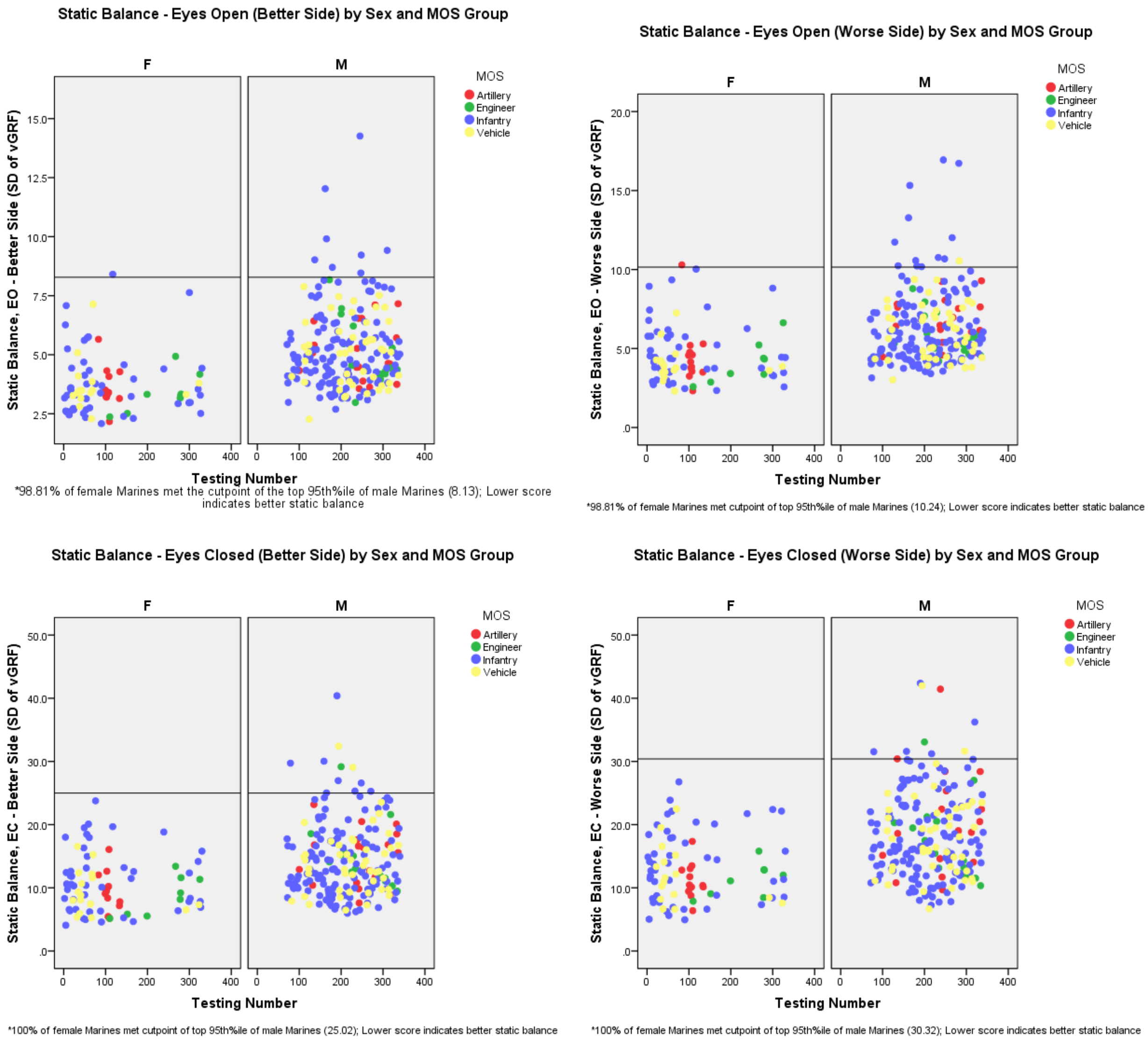

Figure 18. Scatterplots of Static Balance by Sex and MOS Group

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Dynamic Postural Stability Index

Background: Accurate sensory information, as measured through dynamic postural stability, is essential to the performance of complex motor patterns, maintaining joint stability, and preventing injury. Deficits in this area may indicate a greater risk for ankle and knee injury.

Purpose: Examine dynamic postural stability through a jump landing (lower values are indicative of better balance)

Testing methodology:
Kistler force plate
Average of 3 trials
Begin with two-legged stance, clear hurdle, land on single leg

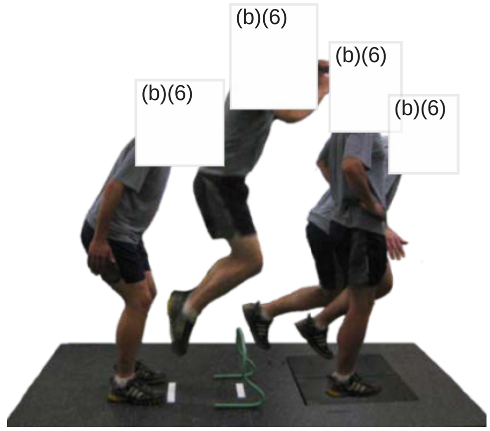


Figure 19. Dynamic Jump Landing

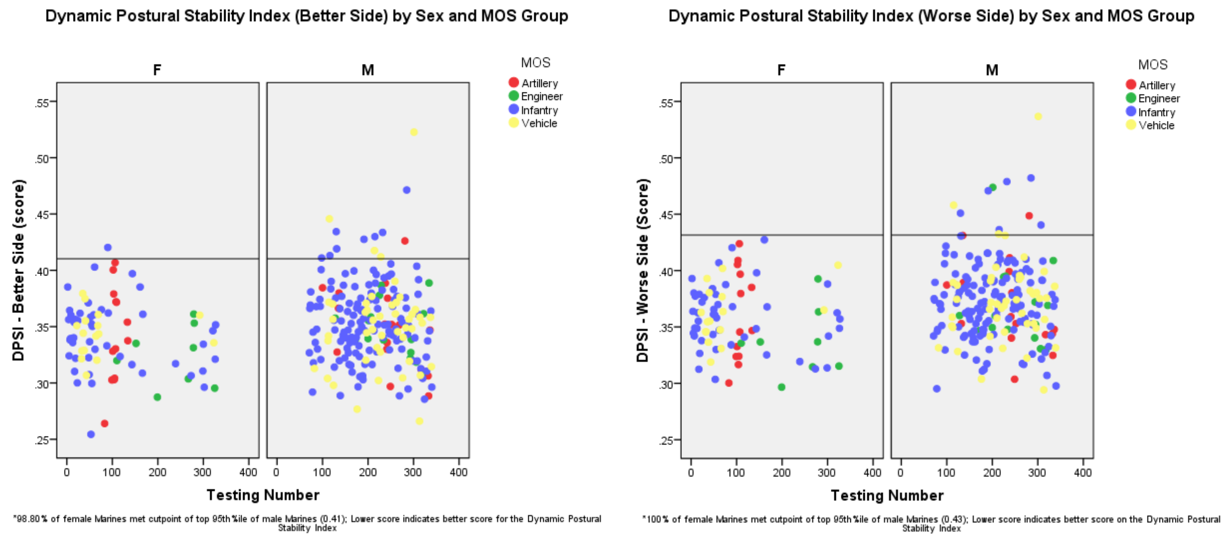


Figure 20. Scatterplots of Dynamic Postural Stability Index by Sex and MOS Group

<u>**Sensory Organization Test**</u>

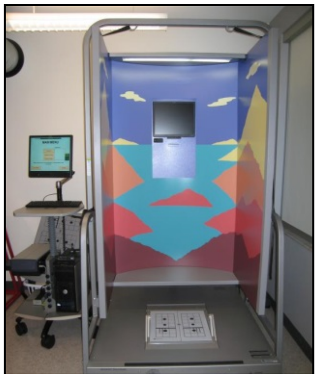


Figure 21. NeuroCom Sensory Organization Test

Background: Accurate sensory information, as measured through targeted sensory testing, is essential to the performance of complex motor patterns, maintaining dynamic joint stability, and preventing injury, especially in environments where the surrounding visual field and terrain change frequently and quickly. Deficits in the ability to efficiently and effectively select and use different sources of sensory information may result in a greater risk for lower back and lower limb injury. The Sensory Organization Test assesses the ability to use input from the somatosensory, visual, and vestibular systems to maintain balance.

Purpose: Examine postural stability

Testing methodology:
Neurocom; Average of 3 trials during six different testing conditions

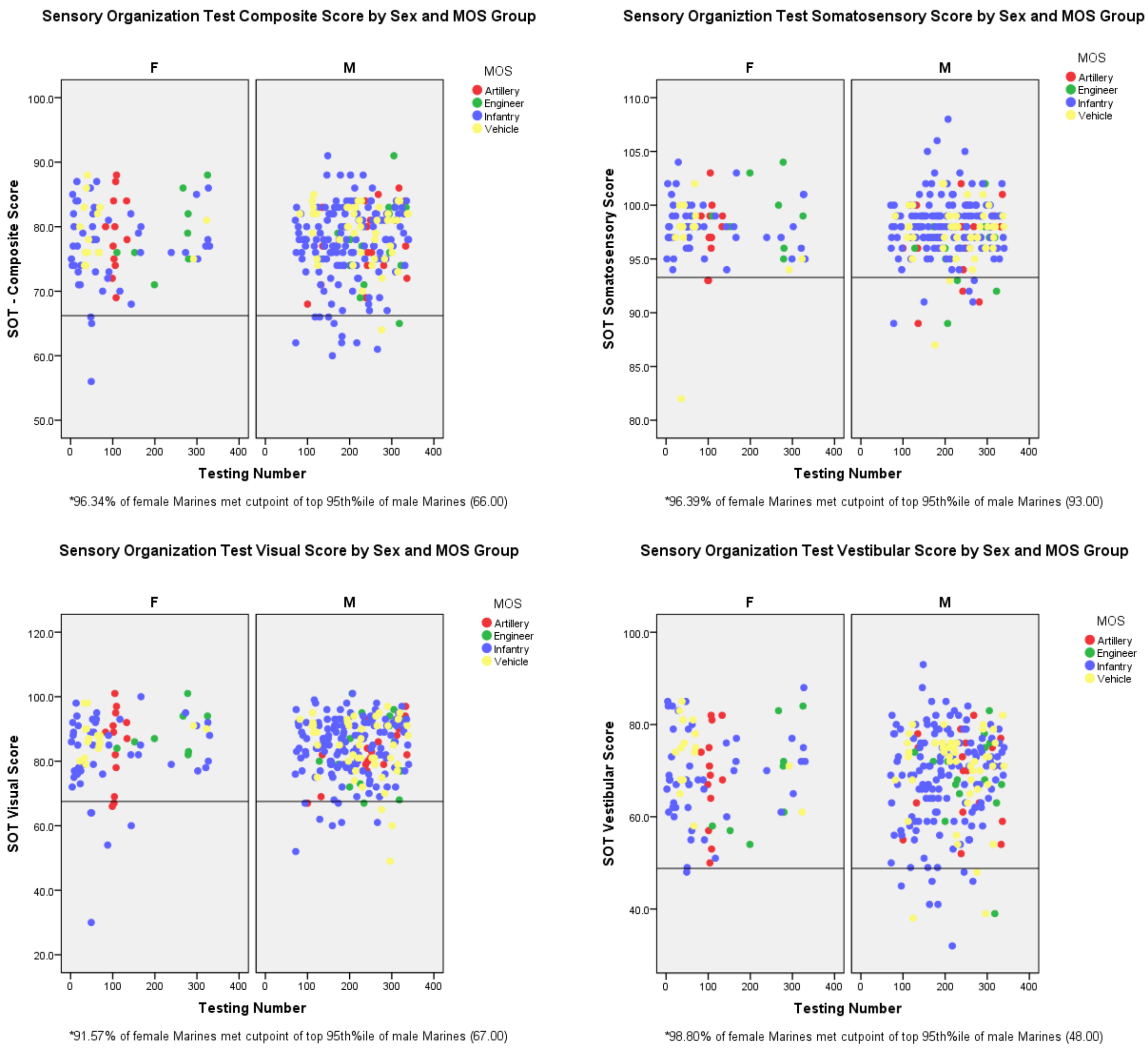


Figure 22. Scatterplots of Sensory Organization Test Scores by Sex and MOS Group

Laboratory Biomechanical Variables

<u>Hip and Knee Kinematics: Dynamic jump landing (two legged takeoff, one legged landing)</u>

Background:

The musculature surrounding the hip and knee play an essential role in lower extremity dynamic stability. Landing with greater flexion at the hip will allow for more efficient use of the strong muscles of the hip and absorption of joint forces. Flexing the knee at landing and throughout dynamic tasks is essential to and dissipating landing forces experienced throughout the lower extremity. Inadequate knee flexion combined with a valgus knee angle (knock-kneed) can increase the strain on knee ligaments, which can lead to tissue failure and injury.

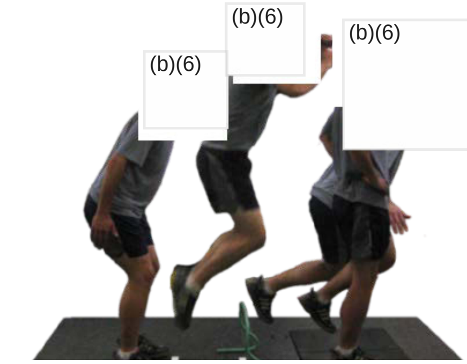


Figure 23. Dynamic Jump Landing

Purpose:

Examine hip and knee flexion angles (°) at initial contact and maximum knee flexion (°)

Testing methodology:

3D optical capture system (Vicon, Centennial, CO)

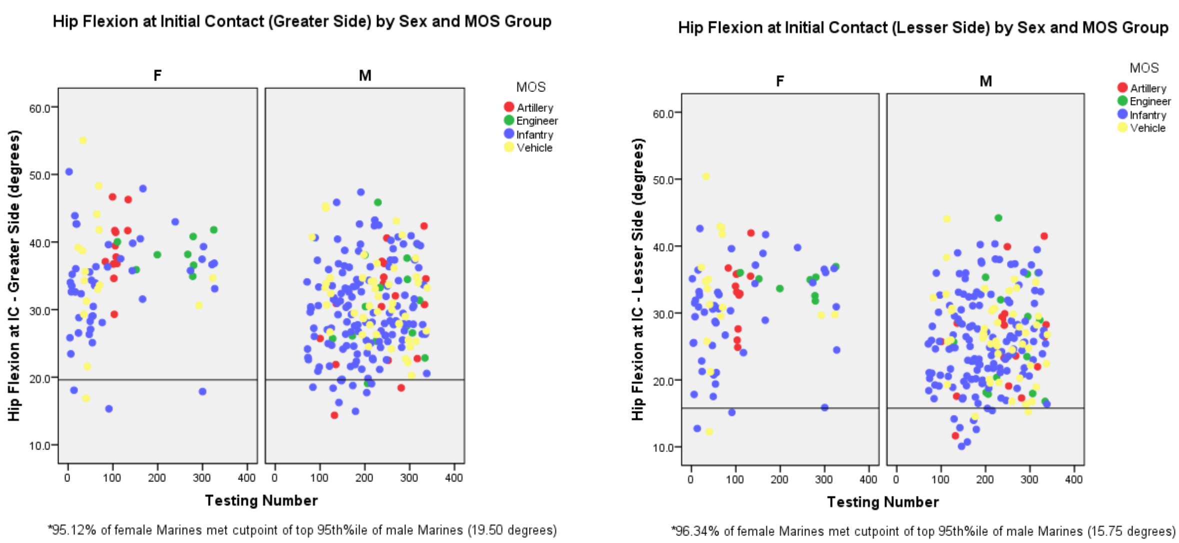


Figure 24. Scatterplots of Hip Flexion at Initial Contact by Sex and MOS Group

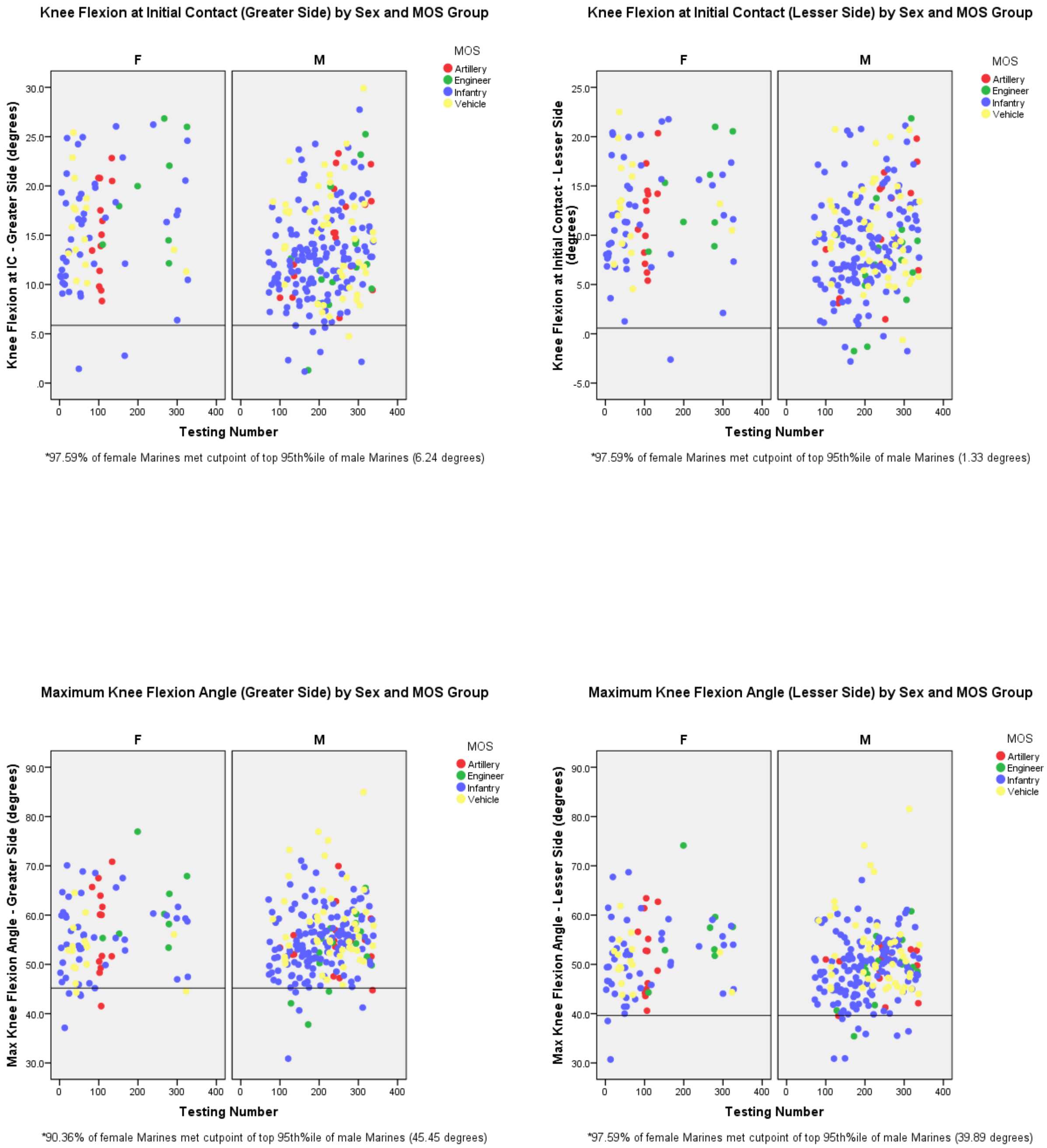


Figure 25. Scatterplots of Knee Flexion at Initial Contact and Maximal Angle by Sex and MOS Group

Ground Reaction Forces: Dynamic jump landing (two legged takeoff, one legged landing)

Background: Greater vertical ground reaction forces directly correlate with higher joint forces. Individuals who are able to decrease landing forces through modified landing strategies should be able to mitigate these forces and reduce the risk of injury.

Purpose: Examine peak vertical ground reaction forces

Testing methodology:
Kistler force plates (Kistler Corp, Worthington, OH); Collected at 1200 Hz

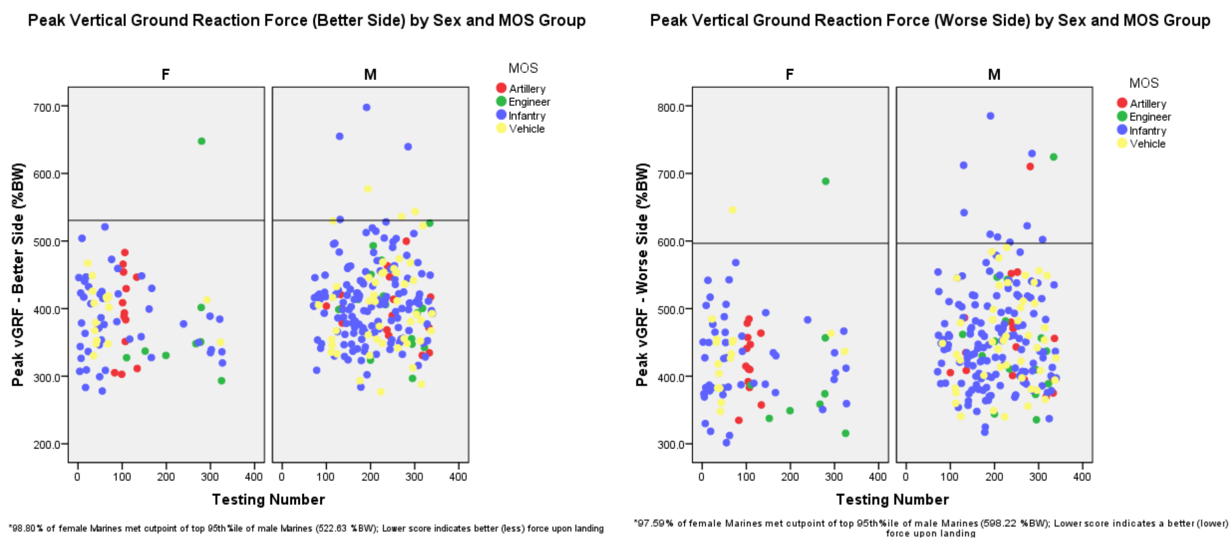


Figure 26. Scatterplots of Peak Vertical Ground Reaction Force by Sex and MOS Group

Laboratory Physiological Variables

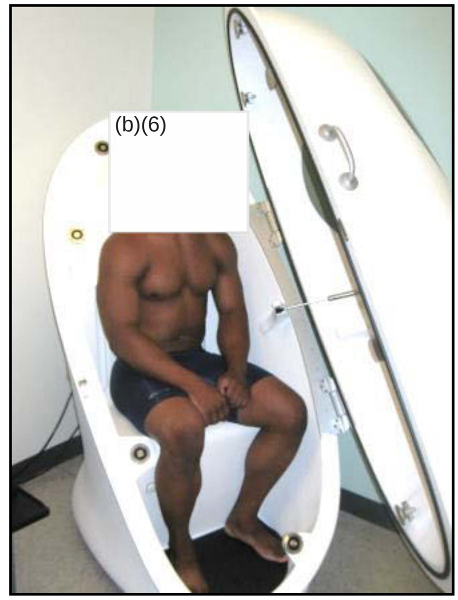


Figure 27. Bod Pod Body Composition Testing

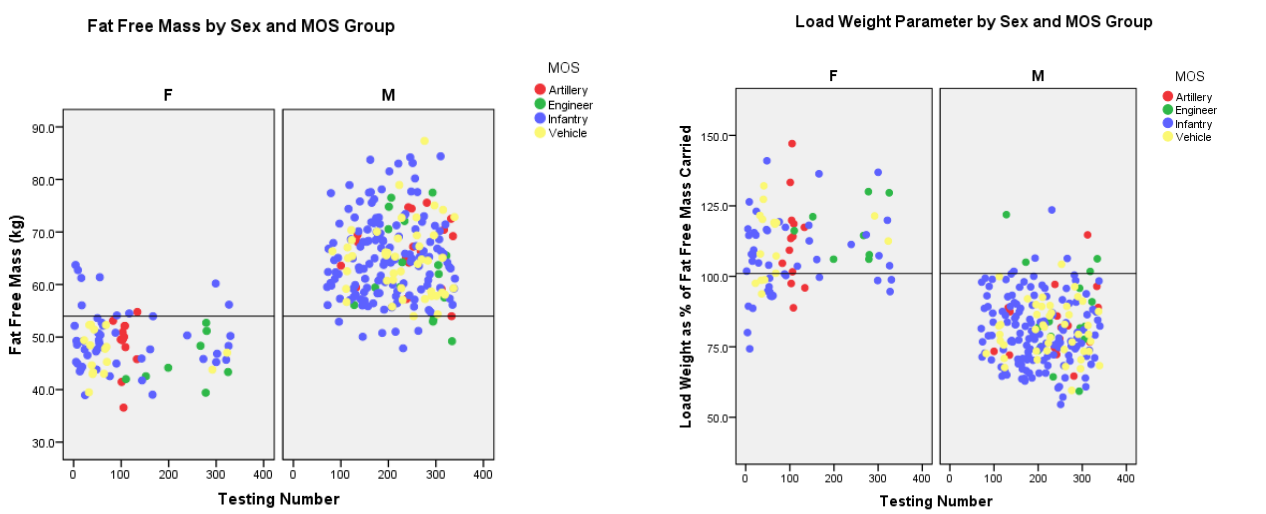
<u>Body Composition</u>

Background:
Optimal performance can be further improved by increasing the lean tissue mass (muscle) within the body, ultimately increasing strength and reducing the effects of fatigue due to excessive body mass due to higher body fat. However, too little body fat also has been shown to negatively affect athletic performance as low essential fat stores interfere with the normal physiological processes of the body, increase the risk of injury, and prolong injury recovery. Very low body fat stores may decrease the available fuel to sustain prolonged training and combat missions.

An optimal body composition distribution is needed to meet the varying terrains and environmental conditions. From a long-term health prospective, less but optimal body fat may decrease the risk of hypokinetic diseases (i.e. cardiovascular disease, diabetes, hypertension, hypercholesterolemia).

Purpose: Examine body composition (fat mass/fat free mass)

Testing methodology:
BOD POD body composition tracking system (Cosmed, Chicago IL)



*11.90% of female Marines met cutpoint of top 95th%ile of male Marines (53.97 kg)

*29.76% of female Marines met cutpoint of top 95th%ile of male Marines (101 degrees); lower Load Weight indicates Marine is carrying less percent of FFM as fighting load or fat mass

Figure 28. Scatterplots of Fat Free Mass and Load Weight Parameter by Sex and MOS Group

Anaerobic Power/Anaerobic Capacity

Background: The development of lower extremity overuse injuries has been associated with low levels of physical fitness. Suboptimal levels of anaerobic power (short duration bursts of high intensity exercise) and anaerobic capacity (prolonged duration high intensity exercise) along with other diminished physiological characteristics have been related directly to an increased risk of injury and impaired performance. Anaerobic power and anaerobic capacity are critical when high intensity, high stress bouts are followed by the need for tactical performance (e.g., gun firing).

Purpose: Examine anaerobic power/anaerobic capacity

Testing methodology:
Velotron cycling ergometer (RacerMate, Inc., Seattle, WA)
Measuring range: 5 to 2000 watts
Accuracy: +/- 1.5%; Repeatability: +/- 0.2 % or better

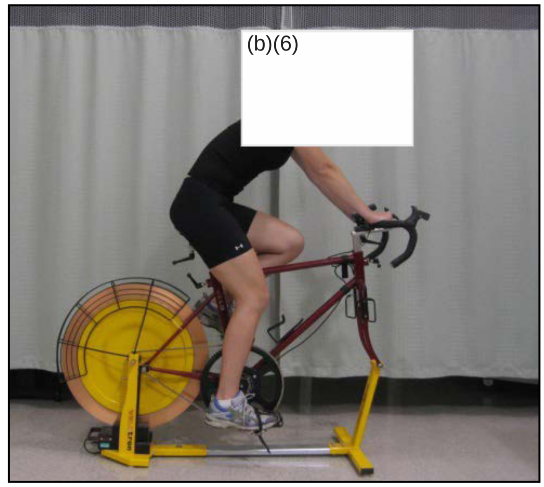


Figure 29. Wingate 30-sec Anaerobic Cycle Test

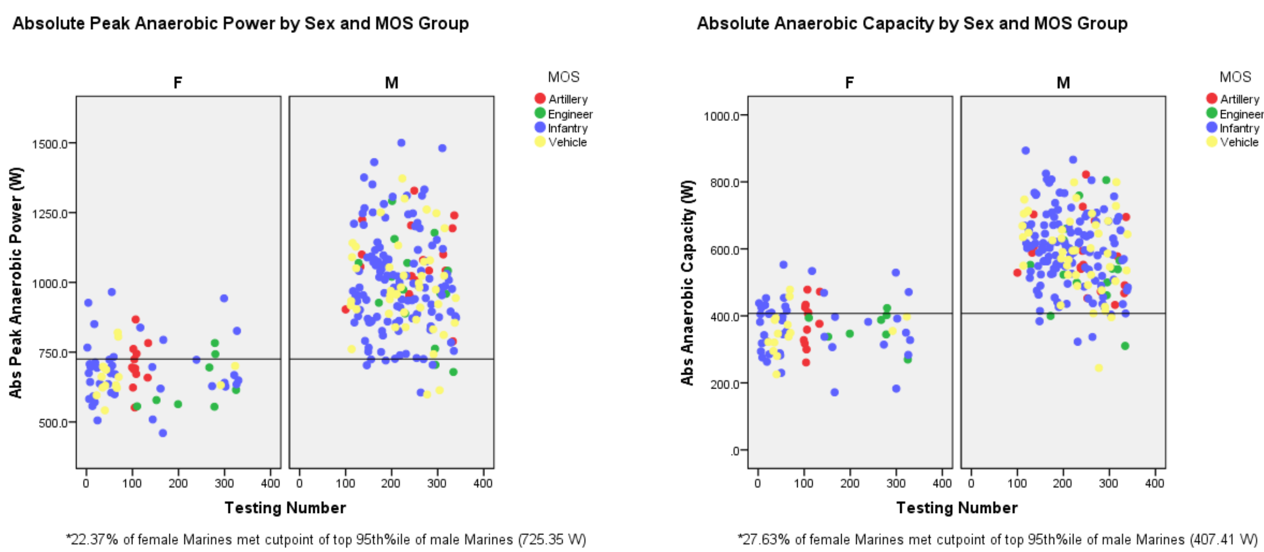


Figure 30. Anaerobic Power and Capacity Scatterplots by Sex and MOS Group

Aerobic Capacity

Background:
The development of overuse injuries has been associated with low levels of physical fitness. A significant relationship has been reported between less aerobically fit athletes and trained individuals and increased injuries compared to those who are more fit. Suboptimal levels of maximal oxygen consumption and lactate threshold have been directly related to an increased risk of injury and impaired performance as premature fatigue results. Improvements in maximal oxygen consumption and lactate threshold with training will permit workout levels at higher intensities for longer durations without the accumulation of blood lactate to impair performance, while making the Marine more fatigue resistant.

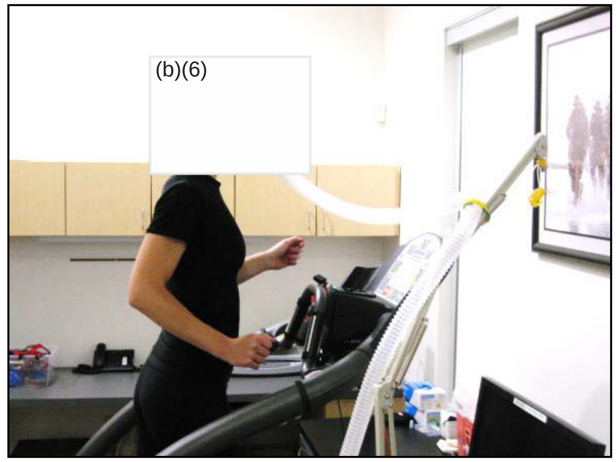


Figure 31. Maximal Treadmill Exercise Test for Aerobic Capacity and Lactate Threshold

Purpose: Examine aerobic capacity (VO_2max/lactate threshold)

Testing methodology:
TrueOne 2400 Metabolic Unit (ParvoMedics, Sandy UT); LactatePro blood lactate test meter (Arkray, Japan)

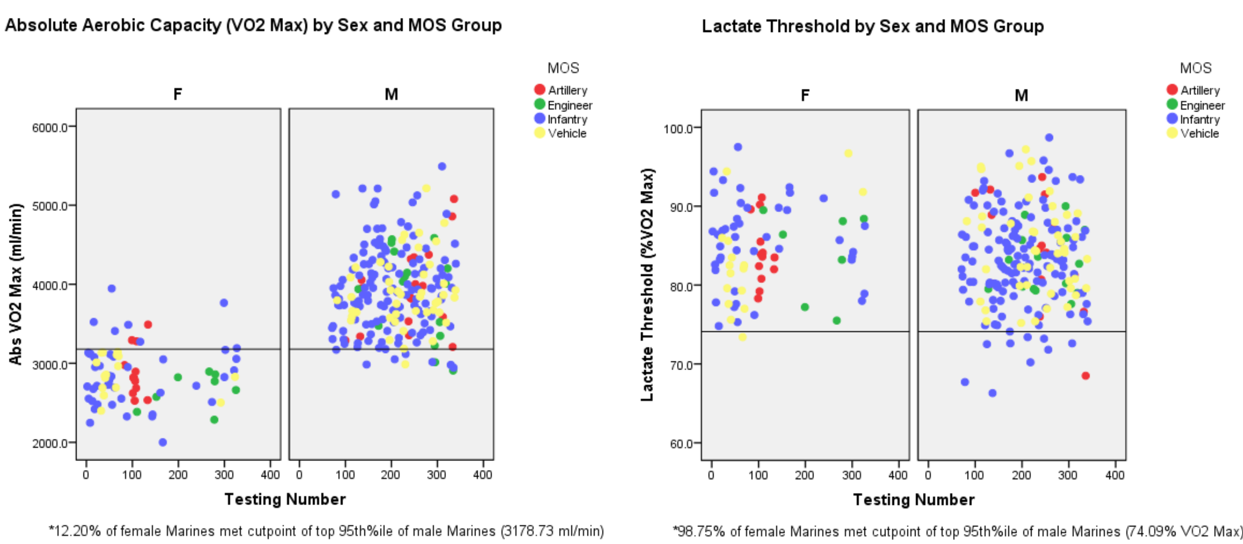


Figure 32. Scatterplots of Aerobic Capacity and Lactate Threshold by Sex and MOS Group

UPitt Field Variables

<u>Field Performance Data</u>

Purpose:
Evaluate upper and lower body anaerobic power, flexibility, and agility using field-friendly assessments

Testing methodology:
Anthropometric Data (arm span, leg length)
Medicine ball toss (upper body anaerobic power)
Standing broad jump (lower body anaerobic power)
Sit and Reach (lower back and hamstring flexibility)
Pro-Agility (5-10-5) Drill
Functional Movement Screen*

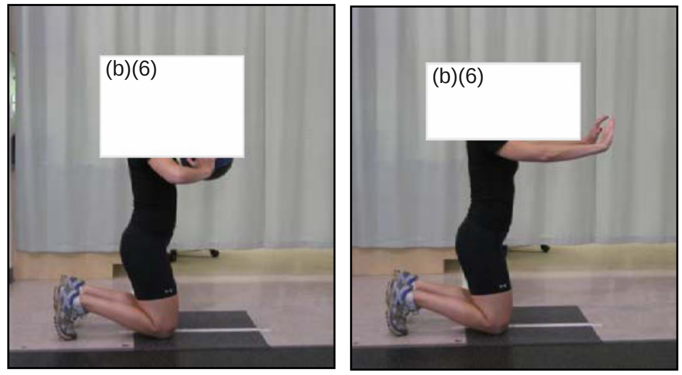


Figure 33. Medicine Ball Toss Testing

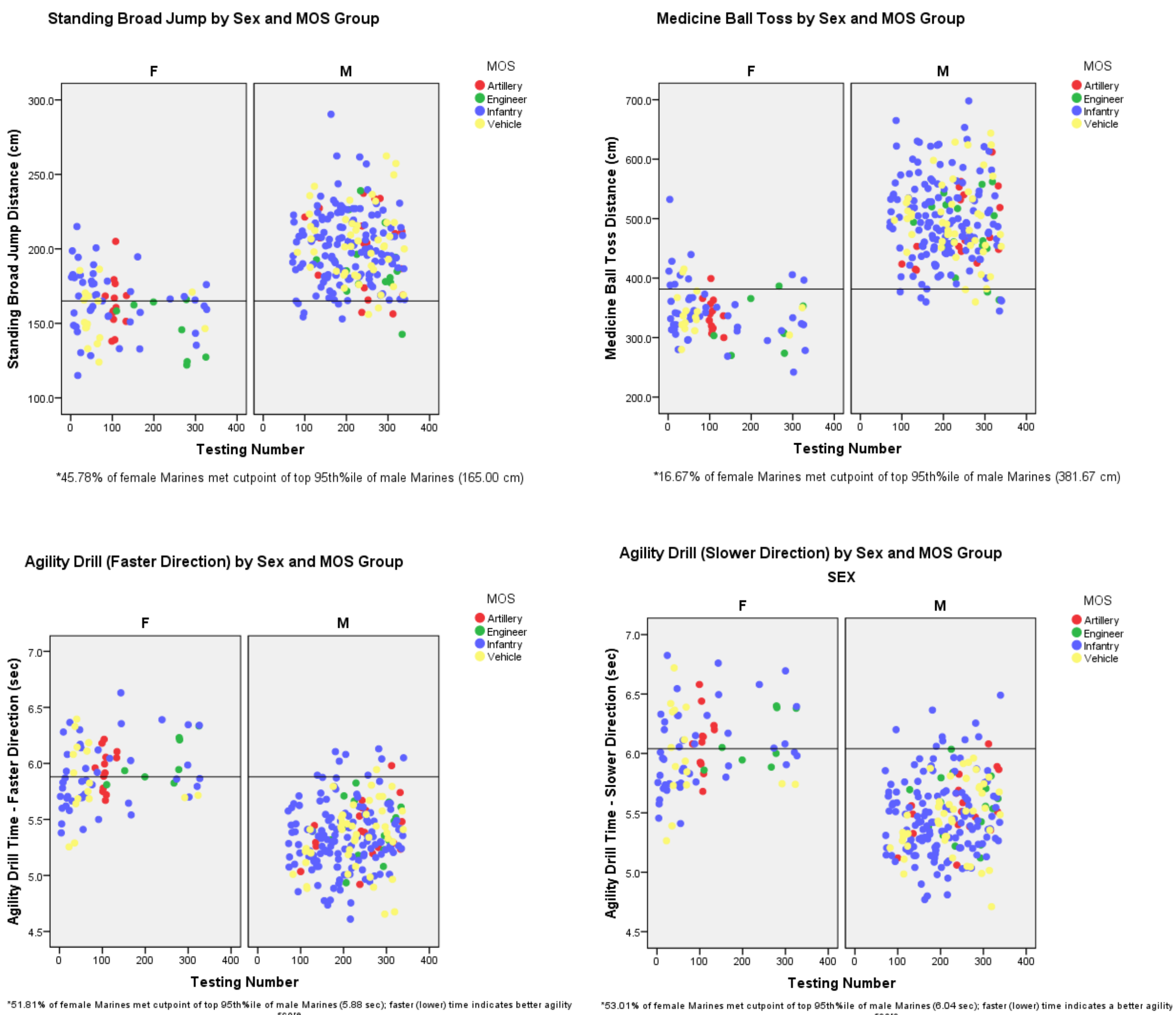


Figure 34. Scatterplots of Field Variables by Sex and MOS Group

**Functional Movement Screen scores were comparable between male and female Marines*

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Resiliency Analysis – Changes in Characteristics over Time

Pre- to Post Entry Level Training Changes
Changes in UPitt laboratory and field variables from pre- to post-MOS school were evaluated utilizing paired t-tests and Wilcoxon signed rank tests (where appropriate) for female Marines who graduated MOS School:

- Absolute and normalized trunk flexion strength and absolute and normalized ankle eversion and inversion strength significantly increased
- Hamstring flexibility (active knee extension flexibility) and left torso rotation flexibility significantly decreased
- Both static balance on the right side under eyes-open conditions and left dynamic postural stability index significantly improved
- Both the somatosensory and visual scores of the Sensory Organization test significantly improved
- Right hip flexion at initial contact significantly increased but left knee flexion at initial contact significantly decreased
- Body fat percentage (measured by the Bod Pod) significantly decreased and fat free mass significantly increased
- Peak anaerobic power and mean anaerobic capacity during the cycling test significantly decreased, but medicine ball toss distance significantly increased
- Agility drill in both the right and left directions became significantly slower

Baseline to Interval and Baseline to Post-GCE ITF Variable Changes between Gender
An analysis was conducted to determine if changes in variables from baseline to interval testing were significantly different between male and female Marines. The following significant differences were demonstrated:

- Changes in left shoulder external/internal rotation strength ratio were significantly different between male and female Marines (male and females both increased, but females demonstrated a higher change in this variables)
- Changes in normalized trunk flexion strength were significantly different between male and female Marines (male Marines increased trunk flexion strength, while female Marines decreased trunk flexion strength)
- Changes in Sensory Organization Test composite score were significantly different between male and female Marines (male Marines increased this score, while female Marines decreased this score)
- Changes in agility drill time in the left direction were significantly different between male and female Marines (male Marines became faster, while female Marines became slower)

An analysis was conducted to determine if differences in variables from baseline to post-GCE ITF testing were significantly different between male and female Marines. The following significant differences were demonstrated (field tests were not collected during post-testing):

- Changes in absolute and normalized left shoulder external rotation strength were significantly different between male and female Marines (male Marines decreased shoulder external rotation strength, while female Marines increased shoulder external rotation strength)
- Changes in absolute and normalized left torso rotation strength were significantly different between male and female Marines (male Marines decreased torso strength, while female Marines increased torso rotation strength)

Baseline to Interval Changes
Changes in UPitt laboratory and field variables from baseline, pre-ITF check-in to interval testing were evaluated utilizing paired t-tests and Wilcoxon signed rank tests (where appropriate) for both male and female Marines. As a combined group, the following significant changes were demonstrated:

- Absolute and normalized left shoulder internal rotation strength significantly decreased
- Absolute and normalized bilateral knee flexion strength and absolute and normalized bilateral ankle eversion and inversion strength significantly increased
- Left Knee flexion/extension ratio significantly increased
- Torso rotation flexibility significantly decreased
- Dynamic postural stability index scores and visual and vestibular scores on the Sensory Organization Test significantly improved
- Static balance on the left side under eyes-closed conditions significantly worsened
- Left knee flexion at initial contact significantly increased
- Left peak vertical ground reaction force during the jump landing significantly decreased (improved)
- Peak anaerobic power and mean anaerobic capacity during the cycling test significantly decreased, but medicine ball toss distance significantly increased
- VO2 Max significantly increased
- Body fat percentage (measured by circumference taping) significantly increased

When assessing changes from baseline to interval testing for males and females separately, male Marines demonstrated the following significant changes:

- Absolute and normalized knee flexion strength and flexion/extension ratio significantly increased
- Absolute and normalized ankle eversion and inversion strength significantly increased
- Torso rotation flexibility significantly decreased
- Dynamic postural stability index scores and the overall composite, somatosensory, visual and vestibular scores on the Sensory Organization Test significantly improved
- Left knee flexion at initial contact significantly increased
- Left peak vertical ground reaction force during the jump landing significantly decreased (improved)
- Peak anaerobic power and mean anaerobic capacity during the cycling test significantly decreased, but medicine ball toss distance significantly increased
- VO2 Max significantly increased
- Agility drill was significantly faster in the left direction
- Body fat percentage (measured by circumference taping) significantly increased

When assessing changes from baseline to interval testing for males and females separately, female Marines demonstrated the following significant changes:

- Absolute and normalized left shoulder internal rotation strength significantly decreased and left external/internal strength ratio significantly increased
- Absolute and normalized trunk extension strength significantly decreased
- Absolute and normalized ankle eversion and inversion strength significantly increased
- Torso rotation flexibility significantly decreased
- Somatosensory score on the Sensory Organization Test significantly increased
- Static balance on the left side under eyes-open conditions significantly worsened
- Peak anaerobic power during the cycling test significantly decreased

Baseline to Post-GCE ITF Testing Changes

Changes in UPitt laboratory and field variables from baseline, pre-GEC ITF check-in to post-GCE ITF testing were evaluated utilizing paired t-tests and Wilcoxon signed rank tests (where appropriate) for both male and female Marines. As a combined group, the following significant changes were demonstrated (field tests were not collected during post-testing):

- Absolute and normalized shoulder internal rotation strength and left shoulder external rotation strength significantly decreased
- Shoulder external/internal strength ratio significantly increased
- Absolute and normalized right knee extension significantly decreased
- Absolute and normalized trunk flexion and extension strength significantly decreased
- Absolute and normalized right ankle eversion and inversion strength and left normalized ankle inversion strength significantly increased
- Right torso rotation flexibility significantly decreased
- Dynamic postural stability index scores and composite score, visual and vestibular scores on the Sensory Organization Test significantly improved
- Static balance on the left side under eyes-open and eyes-closed conditions significantly worsened
- Body fat percentage (measured by the Bod Pod) significantly decreased and fat free mass significantly increased
- Peak anaerobic power measured during the cycling test significantly decreased

When assessing changes from baseline to post-GCE ITF testing for males and females separately, male Marines demonstrated the following significant changes (field tests were not collected during post-testing):

- Absolute shoulder internal rotation and left shoulder external rotation strength and normalized left shoulder internal external rotation strength significantly decreased
- Absolute and normalized right knee extension strength significantly decreased
- Right and left knee flexion/extension strength ratio significantly increased
- Absolute and normalized trunk flexion strength significantly decreased
- Absolute left torso rotation strength significantly decreased
- Absolute and normalized right ankle eversion and inversion strength significantly increased
- Peak anaerobic power during the cycling test significantly decreased

When assessing changes from baseline to post-GCE ITF testing for males and females separately, female Marines demonstrated the following significant changes (field tests were not collected during post-testing):

- Absolute and normalized right shoulder internal rotation strength significantly decreased and left external/internal strength ratio significantly increased
- Absolute right knee extension strength and normalized right and left knee extension strength significantly decreased, and right knee flexion/extension strength ratio significantly increased
- Absolute and normalized trunk extension and flexion strength significantly decreased
- Right torso rotation flexibility significantly decreased
- Composite score on the Sensory Organization Test significantly increased
- Left hip flexion at initial contact significantly decreased
- Fat free mass significantly increased

Nutritional Profiles

Energy Requirements for Physical Training and Weight Goals

Background:
Energy expenditure data of military personnel reported in the literature has ranged from 3100 to over 8000 kcals per day. The large range reflects differences not only in the volume, intensity, operational and environmental demands of the physical activity being performed, but in the variety of methods used to obtain the data. Although the daily total energy expenditure (TEE) of the Marines has not been quantified, estimations of energy needs can be calculated using reported physical activities and the Cunningham equation. The Cunningham equation uses fat free mass to calculate resting energy expenditure. TEE is then calculated by adding the estimated energy needs from physical activity to resting energy expenditure.

Purpose:
To determine the amount of calories consumed on a daily basis and compare it to the calories required to fuel daily physical training as well as obtain the Marines weight and body composition goals.

Testing methodology:
Nutrition/Exercise History and 24 hour Diet Recall (Phase 1)
Portable Respiratory Metabolic System (Phase 2)

Summary:
Energy intake and expenditure data and weight goals and energy intake are presented in Table 7 and Table 8. Forty-three percent of the Marines expressed wanting to lose weight, followed by maintaining (38%), and wanting to gain weight (26%). Thirty-nine percent of Marines wanting to gain weight are not consuming adequate calories to meet their goals. Twenty-one percent of the Marines who indicated wanting to lose weight are consuming excess calories (greater than 110% of needs). Further, only 11% of Marines wishing to maintain their current weight are consuming adequate calories for weight maintenance (between 90-110% of needs).

Underreporting food intake, a limitation of self-reported food intake, may contribute to the high number of individuals who have a recorded intake less than their estimated energy requirements.

**Important to note, these are only estimates of energy expenditure based on a formula and not measured energy needs.

Carbohydrate Requirements for Physical Training

Background:
Carbohydrate is the major fuel source for skeletal muscle and the brain. In the muscle, stored carbohydrate (glycogen) can be used for both anaerobic (short-term, high-intensity) and aerobic (endurance) activity. During prolonged strenuous physical activity, muscle glycogen and blood glucose are the major substrates for oxidative metabolism. Research has shown that CHO intake will also improve performance on military tasks.

Purpose:
Carbohydrates (CHO) should be provided based on training time and body weight in order to individualize specific muscle fuel needs for the Marines. The aim is to achieve carbohydrate intakes to meet the fuel requirements of the training program and to optimize restoration of muscle glycogen stores between workouts so that the Marines are able to perform maximally and are combat ready more quickly.

Testing methodology:
Nutrition History and 24 hour Diet Recall

Grams Carbohydrate/kg body weight/day	Training
3-5 g/kg/day	Typical US Diet (low activity)
5-7 g/kg/day	General training activities
6-10 g/kg/day	Endurance athletes

Summary:
Carbohydrate requirements were estimated based physical training using the following and are presented in Table 9, Table 10, and Table 11. When carbohydrate reserves are depleted during/after physical training and are not sufficiently replaced with adequate amounts of daily carbohydrate, there is a switch to a fat-predominant fuel metabolism which is characterized by muscle and central fatigue and the inability to maintain power output. Ultimately this results in a decrease in physical performance. In order for the Marines to train at a higher level, it is vital they consume sufficient carbohydrates on a daily basis. Currently, only 23% of Marines are eating the recommended amount of carbohydrate on a daily basis to fuel muscles for higher intensity longer duration physical training. The majority of those tested are currently not meeting the recommended amount of carbohydrate to optimally replace muscle glycogen.

Protein Requirements for Increasing Muscular Strength and Endurance

Background:
A protein intake between 1.2 and 1.7 g per kg of body mass should adequately meet the possibility for added protein needs during strenuous physical training. Protein requirement for strength trained individuals is on the higher side of the range (1.6-1.7g/kg body weight) allowing additional protein necessary to increase muscle mass, strength, and or power. Equally or more important to increase muscle strength and size is the provision of additional calories above the amount necessary for maintenance.

Purpose:
Examine protein intake as it relates to increasing muscular strength and power

Testing Methodology:
Nutrition History and 24 hour Diet Recall

Protein Requirements: 1.2-1.7 g/kg body weight (bw) for endurance to strength trained athletes

Summary:
Protein intake and protein requirement data are presented in Table 12 and Table 13. Currently, 18% of the Marines are meeting their estimated protein requirements for moderate to heavy physical training. Fifty one percent of the Marines fell below the recommended range, while 26% exceeded their protein requirements.
In order to increase muscle strength and endurance, the right environment for weight gain and increasing muscle mass must be present. One in which protein requirements are met, and estimated energy needs are met or exceeded. Four percent of the Marines are meeting their estimated protein requirements and exceeding estimated energy needs. Thirty percent of the Marines are meeting their protein needs, but are not meeting their estimated energy needs. Fifty one percent of the Marines fell below the recommended protein range and did not consume adequate calories to meet energy needs. Consuming suboptimal calories and protein will result in decreased body mass, muscle strength, size, and power output.

*Underreporting food intake may also contribute to the higher number of individuals who may have a reported intake less than their estimated energy requirements.

Distribution of Fat in the Diet

Background:
Fat along with carbohydrate is oxidized in the muscle to supply energy to the exercising muscles. The extent to which these sources contribute to energy expenditure depends on a variety of factors, including exercise duration and intensity, nutritional status, and fitness level. In general as exercise duration increases, exercise intensity decreases and more fat is oxidized as an energy substrate. During high intensity physical training, predominantly carbohydrate is oxidized to fuel the muscles. To improve physical performance, individuals need to consume enough calories, carbohydrates, and protein to support the demands of training in order to train at a higher level. In planning a diet to provide the nutrients to support the training program, carbohydrate and protein needs are determined first and then the remaining calories are designated to fat which typically ranges from 0.8-2.0 g fat per kg body weight based on caloric needs, body composition goals and duration and intensity of training.

Purpose:
In order to maximize physical performance, it is essential to provide adequate calories, carbohydrate and protein in the diet. Once carbohydrate and protein needs are met, the balance of calories can be supplied by fat in the range of 0.8-1.0 g (moderate PT) to 2.0 g (heavy PT longer duration >4 hours/day) fat per kg body weight.

Testing Methodology:
Nutrition History and 24 hour Diet Recall

Summary:
Fat intake and distribution data are presented in Table 14 and Table 15. To train at an optimal level, it is important to consume sufficient calories, carbohydrates, protein and some fat. However, if foods high in fat replace carbohydrate and protein foods in the diet, such that these two macronutrients fall below recommended amounts, it may impair physical performance. It is recommended that Marines decrease the amount of fat in the diet and increase carbohydrate and protein foods (lower in fat) to better fuel their bodies for physical training and to improve body composition.

Fifty-one percent of Marines fell within the recommended range for fat intake. Thirty-six percent consumed less than 0.8g fat per kg body weight/day, while 13% exceeded 2.0g fat per kg body weight/day. Those Marines who exceeded their estimated energy requirements also had the highest fat consumption and therefor may be missing essential nutrients for adequate fueling and muscle building/recovery.

From a health prospective, the Dietary Reference Intakes (DRIs) have defined an Acceptable Macronutrient Distribution Range (AMDR) for fat as 20-35% of daily energy needs for all adults. The AMDR is defined as a range in intakes for a particular energy source that is associated with reduced risk of chronic diseases while providing adequate intake of essential nutrients. Although the DRIs specify a dietary fat intake range of 20-35% of total calories, for individuals who are involved in daily hard physical training and are trying to acquire or maintain a lower body fat composition, consuming fat in the range of 20-30% may be more beneficial.

Seventy-one percent of Marines currently are consuming a diet that is >30% of calories from fat. High fat diets increase the risk for obesity, high body fat, high blood pressure, diabetes mellitus, and cardiovascular disease. Decreasing the overall fat content of the diet and replacing the calories with high carbohydrate, moderate protein foods (that are low in fat), would decrease health risk, enhance physical training, and improve body composition.

Adequate Fluids During Exercise to Stay Hydrated and Maintain Energy

Background:
The goal is to provide adequate fluids to avoid dehydration but not in excess to avoid water intoxication. The Marine should be well hydrated when beginning exercise and accustomed to consuming fluid at regular intervals (with or without thirst) during training sessions to minimize fluid losses that may result in a decrease in physical performance. If time permits, consumption of normal meals and beverages will restore euhydration. Individuals needing rapid and complete recovery from excessive dehydration can drink approximately 1.5 L of fluid per kg of body weight lost (23 oz per pound). Consuming beverages and snacks with sodium will help expedite rapid and complete recovery by stimulating thirst and fluid retention.

Purpose:
Examine fluid habits before, during and after exercise

Testing Methodology:
Nutrition History

Summary:
Fluid consumption data is presented in Table 16 and Table 17. The majority of Marines (79%) consume fluid before physical training. The beverage of choice is water followed by "other" drinks. Forty-nine percent of Marines also regularly drink fluids during PT. Water is the preferred beverage; however, if PT lasts longer than 60 minutes, is rigorous, and/or is performed in a hot and humid environment, it may be more beneficial to consume fluids with carbohydrates and electrolytes. Ideally, beverages consumed during training lasting longer than 60 minutes should contain 6-8% carbohydrate as well as 10-20 milliequivalent (mEq) sodium and chloride (constitution of most Sports drinks). Sodium and carbohydrate help speed replenishment of fluid and energy reserves as well as replace sodium lost due to sweating.

All of the Marines consumed fluids following physical training. Water was the most common choice, followed by sports drinks. Ideally, the beverage following physical training should contain carbohydrate, electrolytes, and a small amount of protein. For example, low fat chocolate milk, fruit smoothie or sports drinks that contain protein are good choices. Water along with a snack or meal with carbohydrate, protein, and electrolytes is also sufficient. Consuming a post-exercise beverage or snack/meal containing carbohydrate and protein will provide the essential nutrients for faster muscle recovery.

Timing and Type of Post Physical Training Protein Intake

Background: Immediately after (within 30 minutes) physical training, it is recommended to consume a snack/meal that contains both carbohydrate and a small amount of protein. Nutrient consumption with resistance training stimulates muscle protein synthesis and inhibits the exercise-induced muscle protein breakdown, thereby gradually increasing muscle mass. Consuming a post-exercise snack or meal containing carbohydrate and protein will provide the essential nutrients for faster muscle recovery. Expedited muscle recovery allows an individual to sustain higher physical work capacity (strength and endurance) in subsequent periods of exertion, thus increasing combat readiness.

Purpose:
Examine protein intake and timing after physical training

Testing Methodology:
Nutrition History and 24 hour Diet Recall

Summary:
Nutrient timing data is presented in Table 18. Forty percent of Marines reported eating a snack or light meal before participating in physical training. Of those Marines who consumed a pre-workout snack/meal, 67% ate a snack/meal within 1 hour of PT and 72% consumed a snack/meal that contained carbohydrates and protein. Examples include oatmeal, cereal with fruit, yogurt, breakfast meal, energy bars, and protein shakes. Consuming food prior to PT will provide additional energy and may help to delay fatigue, allowing Marines to perform for a longer duration and/or at a higher intensity for longer periods of time. In addition, including protein prior to exercise may help to minimize the catabolic effect of strenuous exercise on skeletal muscle.

The majority (90%) of the Marines reported eating a snack or a meal after completion of physical training. Of those reporting, 72% consumed a post-workout snack/meal that contained both carbohydrate and protein, such as cereal, milk, fruit, eggs, chicken, toast, or yogurt. Almost half (48%) reported consuming a meal within 30 minutes of completing PT. Ideally, consuming food that contains a moderate amount of carbohydrate and a small amount of protein within 30 minutes of working out will expedite muscle glycogen resynthesis and help to reduce muscle protein breakdown. This is especially important for those Marines participating in subsequent training bouts within 8 hours.

Diet Quality

Background:
The 2010 Dietary Guidelines for Americans (DGA) were developed to improve the health of our Nation's population through nutrition guidelines focusing on health promotion and disease risk reduction. The DGA specifically highlights nutrients and foods to increase/decrease, as well as building healthy eating patterns. Many of the recommendations in the DGA are applicable for all populations regardless of activity level. These guidelines include decreasing the amount of saturated fat in the diet, cholesterol, trans-fatty acids, and alcohol and increasing fruits and vegetables, fiber, whole-grains, low-fat/fat-free dairy, seafood, legumes, calcium, potassium, and vitamin D. These recommendations have been tailored to help mitigate the increasing numbers of diet related chronic diseases like cardiovascular disease, hypertension, diabetes, cancer, and osteoporosis. The Healthy Eating Index (HEI) 2010 is a tool that was developed to assess diet quality and adherence to the 2010 DGA. Higher total HEI scores have been associated with decreased chances for obesity, high blood pressure, metabolic syndrome, decreased high-density lipoprotein levels, and certain types of cancer when compared to lower total HEI scores.

Purpose:
To measure and quantify diet quality from dietary intake

Testing methodology:
24 hour Diet Recall and the 2010 Healthy Eating Index (HEI-2010)

Summary:
Diet quality data is presented in Table 19**.** The total HEI score for all Marines was 45.6 ± 14.1 out of a possible score of 100. The total HEI score was fairly similar between men and women Marines, with women scoring slightly higher. The Marine's diet quality is lower than the national average total HEI score of 52. Both Male and Female Marines scored particularly low in the Green and Bean Vegetable, Whole Grain, Dairy, Seafood and Plant Protein, and Whole Fruit categories. Marines also scored low in the Fatty Acid Ratio category, demonstrating that intakes of saturated fats compared to mono and poly-unsaturated fats were too high. This data indicates that a Marine's diet quality could be improved by including more whole grains, fruits, and vegetables and less saturated fat.

Dietary Supplement Usage

Background:
The use of dietary supplements to promote health and improve physical performance has become increasingly popular among members of the military. The results of surveys indicate usage ranges from 37-81% (Institute of Medicine, 2008). Supplements available to service members range from those that might impart beneficial effects to heath and performance with negligible side effects to other that have uncertain benefit and might be potentially harmful especially give the unique environmental and physical demands of military warfare. Currently, data on dietary supplement usage in special operation forces is lacking. Dietary supplement data is presented in Table 20.

Purpose:
To determine the type and usage of dietary supplements.

Testing methodology:
Nutrition History and 24 hour Diet Recall (Phase 1)

	All	Male	Female
Percent of Marines that Report Taking at Least One Dietary Supplement	43%	43%	46%

Summary:
The results of our survey indicate that the most popular type of dietary supplement reported by the Marines were Whey/Protein Supplements (26%), followed by Omega-3/Antioxidant (15%), and Multivitamin/Minerals and BCAA/Amino Acids (13%) supplements. Nine percent of the supplements reported were in the form of pre-workout supplements, including Jack-3D, Nitric Oxide, or NO-Explode. The effectiveness of NO-Explode as an ergogenic aid is not supported by scientific literature nor have the safety issues been adequately addressed in the athletic or military populations. Previous formulas of Jack-3D contained Geranium Stem extract (DMAA), which behaves like an amphetamine and when combined with caffeine, energy drinks, or other proprietary blend formulas can become a potent stimulant that may lead to serious injury or death. The Food and Drug Administration (FDA) has warned that DMAA is potentially dangerous to health and considers products containing it illegal. Geranium Stem is a banned substance on the NCAA, WADA supplement list, as well as being banned from military bases. The DOD has ordered an end to all on-base sales of supplements that contain DMAA (found in geranium stem extract).

Predictors of Graduation – Ground Combat Element Integrated Task Force MOS School

Point-Biserial Correlations were performed to measure the strength of the association between the outcome (Graduated MOS School vs. Did Not Graduate-Excluding Motivational Drops) and each of the laboratory variables. Significant low positive correlations were demonstrated between the outcome and several variables. Higher absolute and body-weight normalized ankle strength and anaerobic capacity tended to occur in those who graduated MOS School, with slightly higher correlations demonstrated in the normalized data. Higher aerobic capacity also tended to occur in those who graduated MOS school. Further analysis revealed that those who graduate MOS School demonstrated significantly greater absolute and normalized ankle strength, normalized anaerobic capacity, and aerobic capacity as compared to those who did not graduate. Data from this analysis is presented in Table 21.

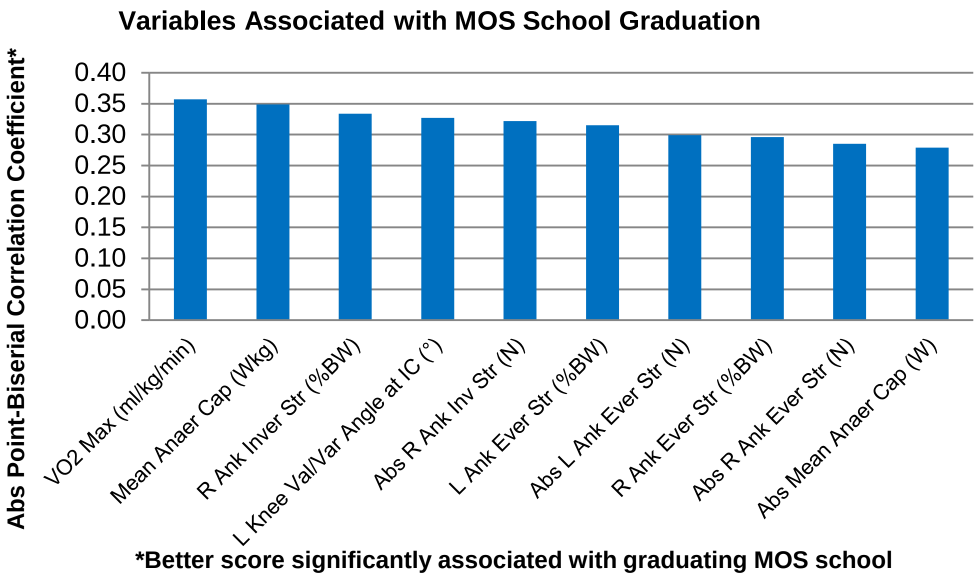


Figure 35. Variables Associated with MOS School Graduation

Predictors of Injury – Ground Combat Element Integrated Task Force

Baseline UPitt laboratory and field variables and USMC PFT/CFT variables were compared between injured (sustaining at least one injury) versus non injured subjects using independent samples t tests (Table 22, Table 23, and Table 24). For this analysis, an injury was defined as any injury to the musculoskeletal system (bones, ligaments, muscles, tendons, etc.) for which medical attention was sought. Separate logistic regression analyses were performed using UPitt Field and USMC PFT/CFT variables only, and then including all UPitt Field and USMC PFT/CFT and UPitt laboratory physiology, absolute strength, flexibility, balance, and lower extremity biomechanical variables. Final models were developed using significant predictors from the previous steps. Separate equations were developed for all subjects, and then separately for male and female subjects. Females were used as the reference category for sex, and history of self-reported injury was assessed for a period of 365 days prior to the laboratory test date.

UPitt Field and USMC PFT/CFT as Predictors
Logistic regression analyses for all subjects combined using field/PFT/CFT variables as predictors (Table 25) showed that standing broad jump (Odds Ratio (OR) = 0.982, p = 0.022) was significantly associated with the odds of injury, meaning that longer standing broad jump distance is associated with decreased odds of injury among all Marines (protective against injury).

When this analysis was repeated within males (Table 26), standing broad jump (OR = 0.976, p = 0.020) was also significantly associated with the odds of injury (protective against injury). A similar analysis among female subjects resulted in no variables being selected as being significantly associated with the odds of injury.

UPitt Laboratory/Field and PFT/CFT as Predictors
The results of the final logistic regression analysis using all UPitt laboratory/field and PFT/CFT variables for the combined group of males and females (Table 27) showed that absolute VO2 Max (OR = 0.999, p = 0.033), absolute shoulder external rotation strength on the weaker side (OR = 0.897, p = 0.011) were significantly associated with the odds of injury, meaning that higher absolute VO2 Max and greater shoulder external rotation strength on the weaker side are associated with decreased odds of injury for all Marines (protective against injury). Absolute torso rotation strength on the weaker side (OR = 1.024, p = 0.004) was also significantly associated with the odds of injury, indicating that greater absolute torso rotation strength on the weaker side is associated with increased odds of injury for all Marines in this analysis.

When this analysis was conducted among male subjects (Table 28), absolute shoulder external rotation strength on the weaker side (OR = 0.885, p = 0.007), absolute torso rotation strength on the weaker side (OR = 1.027, p = 0.005), absolute ankle inversion strength on the weaker side (OR = 0.919, p = 0.044), and peak vertical ground reaction force on the worse side (OR = 1.006, p = 0.025), were significantly associated with the odds of injury in male Marines. These results indicate that greater absolute shoulder external rotation strength and greater absolute ankle inversion strength on the weaker side as well as lesser (more desirable) landing forces are associated with decreased odds of injury (protective against injury), while greater absolute torso rotation strength on the weaker side is associated with increased odds of injury in male Marines. Among female subjects (Table 29), lactate threshold (OR = 1.139, p = 0.013) was significantly associated with the odds of injury, indicating that a higher lactate threshold is associated with increased odds of injury in female Marines.

Specific Aim 2 - Injury Surveillance

Prospective, musculoskeletal injury data were reported by Navy corpsmen during GCE ITF work-up and assessment phases. The following pages contain descriptive injury epidemiology of all volunteers and by males and females for the following categories:

1. Anatomic location of injuries
2. Anatomic sub-location of injuries
3. Cause of injury
4. Injury type
5. Activity when injury occurred
6. Injury onset
7. Mechanism of injury

The following definitions were utilized to describe the injuries within each category:

1. Musculoskeletal injuries: Injury to the musculoskeletal system (bones, ligaments, muscles, tendons, etc.) for which medical attention was sought
2. Time-loss injuries: Resulted in alteration of tactical activities, tactical training, or physical training for a minimum of one day
3. Preventable injuries: Considered to be able to be reduced through injury prevention programs
4. Not-preventable injuries: Not able to be deterred through injury prevention programs, like motor vehicle accidents, direct contact, stepping in a ditch

Summary – Injury Epidemiology

The study period for the recording of musculoskeletal injuries described in this section began with the date of laboratory testing with the University of Pittsburgh, immediately prior to or during ITF training (excludes MOS School), and ended with the last day of ITF training. Corpsman-reported musculoskeletal injuries that occurred during the study period are described in this narrative. Injury was defined as an injury to the musculoskeletal system (bones, ligaments, muscles, tendons, etc.) for which medical advice or evaluation was sought, regardless if the injury or condition resulted in alteration of physical training, tactical training, or activities of daily living. This includes conditions such as sprains, strains, and fractures (broken bones). In addition, contusions (bruises), abrasions/lacerations (cuts), and heat-related illnesses were included if medical attention was sought. Time-loss injuries are injuries or conditions that resulted in alteration of physical training, tactical training, or activities of daily living for a minimum of one day. Data about time-loss injuries have been included in the tables.

A subset of injuries was identified as preventable injuries. Preventable injuries are those that may be reduced through injury prevention programs. Examples include an inversion ankle sprain sustained while walking/running on uneven terrain, low back strain that occurred while lifting a load onto a truck, and non-contact knee sprain during cutting or landing.

The descriptive epidemiology of musculoskeletal injuries included a description of injury count and relative frequency by anatomic location, anatomic sub-location, injury cause, activity when injury occurred, injury type, injury onset, and mechanism of injury.

Musculoskeletal injury data were obtained from 302 subjects. Of these 302 subjects, 84 subjects were females, and 218 subjects were males. Of the 302 subjects, 75 subjects suffered at least one injury during the study period. The proportion of subjects who were injured was significantly greater among female as compared to male subjects (female: 34/84 = 40.5%, male: 41/218 = 18.8%, Fisher's exact test p value <0.001).

The lower extremity was the most frequent location of the injuries, followed by the spine (Table 30). The most frequent anatomic sub-location of the injuries was the foot and toes, followed by the lumbo-pelvic region of the spine (Table 31). Ruck marching was the cause of a large proportion of injuries, followed by running (Table 32). Physical training was the most common activity the subjects were participating in at the time of injury, followed by tactical training (Table 33). The majority of injuries were pain/spasm/ache, followed by sprain (Table 34). Most injuries were acute in onset (Table 35), and the most common mechanism was non-contact (Table 36). Of the 100 musculoskeletal injuries, 65 were classified as preventable.

The lower extremity was the most frequent location of the preventable injuries, followed by the spine (Table 30). The most frequent anatomic sub-location of the preventable injuries was the lumbo-pelvic region of the spine, followed by foot and toes (Table 31). Ruck marching was the most frequent cause for preventable injuries, followed by running (Table 32). The most frequent activity that subjects were participating in when preventable injury occurred was physical training, followed by tactical training (Table 33). The majority of preventable injuries were pain/spasm/ache, followed by strain (Table 34). Most preventable injuries were acute in onset (Table 35), and the most common mechanism was non-contact (Table 36).

Among male Marines, the lower extremity was the most frequent location of the injuries, followed by the spine (Table 37). The most frequent anatomic sub-location of injuries was the foot and toes, followed by the ankle (Table 38). Ruck marching was responsible for a largest proportion of injuries among male subjects (Table 39). Physical training was the most common activity male subjects were participating in when they were injured, followed by tactical training (Table 40). The most common injury type among male subjects was pain/spasm/ache, followed by sprain (Table 41). Most injuries among male subjects were acute in onset (Table 42), and the most frequent mechanism of injury was non-contact (Table 43). Of the 50 musculoskeletal injuries among male subjects, 29 were classified as preventable.

Among male Marines, the lower extremity was the most frequent location of preventable injuries, followed by the spine (Table 37). The most common anatomic sub-location for preventable injuries among male subjects was the foot and toes (Table 38). Among male subjects, ruck marching was the most frequent cause of preventable injuries (Table 39). The most frequent activity that male subjects were participating in when preventable injury occurred was physical training (Table 40). The majority of preventable injuries among male subjects were pain/spasm/ache, followed by stress fracture (Table 41). Most preventable injuries among male subjects were acute in onset (Table 42), and the most common mechanism was non-contact (Table 43).

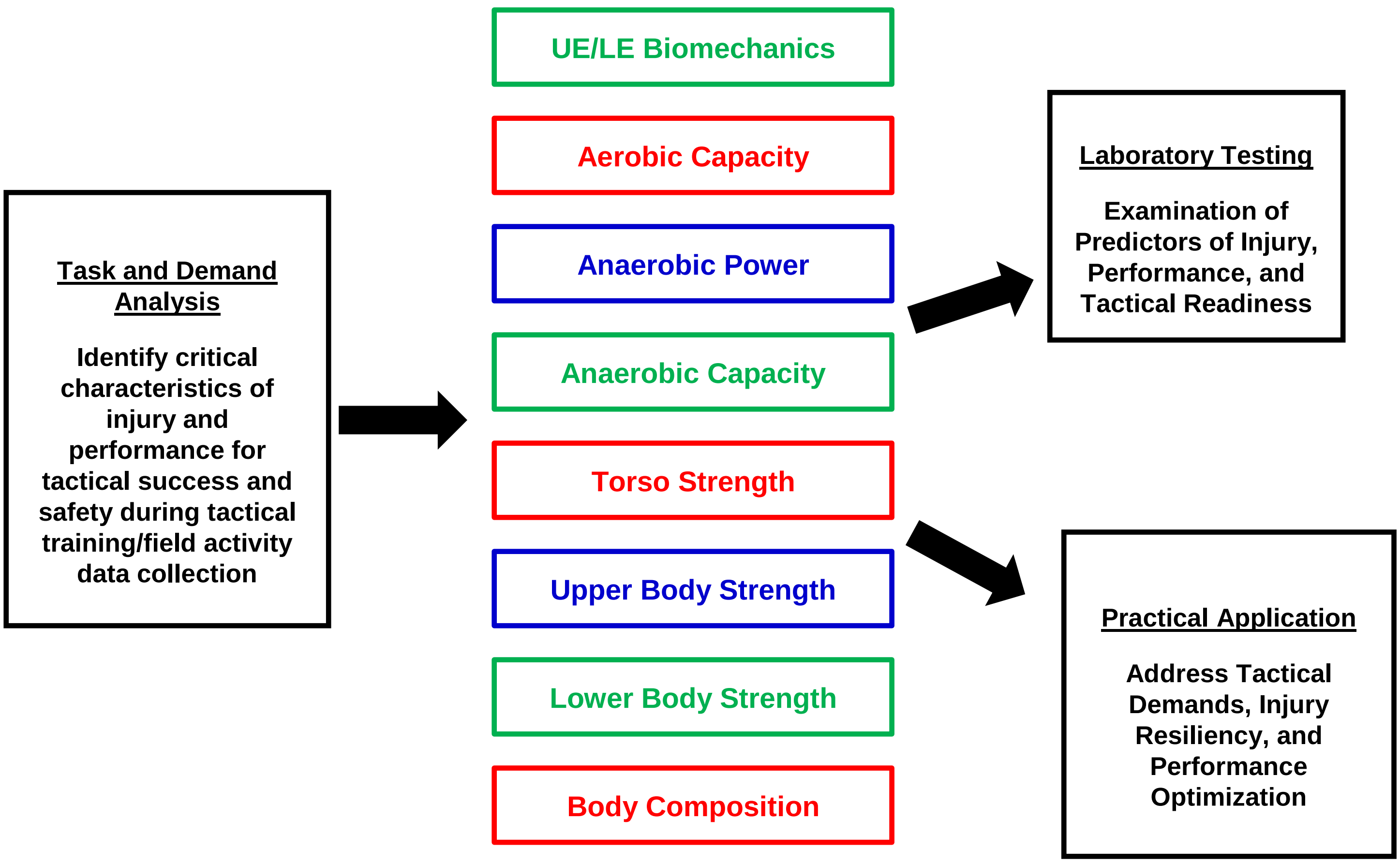
Among female Marines, the lower extremity was the most frequent location of the injuries, followed by the spine (Table 44). The most frequent anatomic sub-location of the injuries were the hip, followed by the foot and toes (Table 45). Ruck marching was responsible for a large proportion of injuries, followed by running (Table 46). Physical training was the most common activity female subjects were participating in when they were injured, followed by tactical training (Table 47). The most common injury type among female subjects was pain/spasm/ache, followed by strain (Table 48). Most injuries among female subjects were acute in onset (Table 49), and the most frequent mechanism of injury was non-contact (Table 50). Of the 50 musculoskeletal injuries among female subjects, 36 were classified as preventable.

Among female Marines, the lower extremity was the most frequent location of preventable injuries, followed by the spine (8/36 = 22.2%) (Table 44). The most common anatomic sub-location for preventable injuries among female subjects was the hip, followed by the lumbopelvic region of the spine (Table 45). Among female subjects, ruck marching was the most frequent cause of preventable injuries, followed by running (Table 46). The most frequent activity that female subjects were participating in when preventable injury occurred was physical training (Table 47). The majority of preventable injuries among female subjects were pain/spasm/ache, followed by strain (Table 48). Most preventable injuries among female subjects were acute in onset (Table 49), and the most common mechanism was non-contact (Table 50).

Specific Aim 3 - Task and Demand Analysis

The purpose of the task and demand analysis is to study the specific musculoskeletal and physiological demands of female and male Marines undergoing tactical/operational assessments. Data collected includes qualitative and analysis of tactical requirements of activities performed in an operational environment. These requirements include the physiological and musculoskeletal parameters that contribute to tactical performance or are associated with injury during tactical activities. This aim evaluated the relationships between laboratory and field test variables and the analysis of tactical requirements.

1) Task and demand description is presented for each broad task within each MOS category
2) Potential injury analysis for each broad task within each MOS category and qualitatively determined related UPitt Laboratory/Field characteristics are presented
3) UPitt Laboratory/Field characteristics identified as critical for successful task completion are presented for each MOS group (Table 51, Table 52, Table 53, Table 54)



Infantry

7 Kilometer Hike and Hole Digging: Marines began the hike with a pack that weighed approximately one hundred and fourteen pounds. Most Marines used a similar technique to get the pack on their back. They would begin by squatting down with their pack resting on the ground, grab the shoulder straps and bring it to their knees. Once it was on their knees, they would standup while flipping the pack over their head and onto their back. The average pace was approximately twenty-five to twenty-seven minutes per mile, with the Marines stopping once during the hike. Once the hike was over, they would start digging a hole. The Marines used two digging techniques, with the first technique mainly just bending at the hips with their legs straight. The second technique had the Marines sitting on the edge of the hole once it was deep enough and digging between their legs. The Marines dug in fifteen minute rotations with their buckets weighed for work output.

Specific movement patterns:

- Pack mounting
    - Lower extremity squat with pack on knee
    - Bilateral shoulder flexion/external rotation to lift and flip pack over head as lower extremities extend to standing
- Ruck marching
    - Added weight of gear (approximately 114 lbs), size/shape of equipment, and terrain may cause suboptimal mechanics during hikes
    - Observed trunk forward lean position to adjust center of mass due to pack weight and lateral shifting to propel advancing lower extremity, particularly on inclined terrain
    - Observed males walking with shorter stride, greater toe out angle compared to females with same pace/ speed due to different physical characteristics (leg length, etc.). Compression and sheer forces through spine due to pack and gear weight.
- Digging
    - Both sitting and standing techniques observed for digging; repetitive lumbar and hip flexion/ extension movements observed

Potential/resultant injury analysis:

- Pack mounting
    - Potential for direct cervical/ spinal trauma when weight of pack makes contact with back
    - Shoulder impingement, strains, and/or instability from flipping motion
- Ruck Marching
    - Cervical and lumbar spine injuries including muscular strains and disc injuries
    - Overuse lower extremity injuries including stress fractures
    - Patellofemoral pain syndrome, iliotibial band syndrome, Achilles tendinopathy, shin splints, plantar fasciitis, and knee and ankle sprains
    - Long-term risks of disc and lower extremity cartilage damage
- Digging
    - Lumbar strain/ disc injury
    - Shoulder overuse injuries including tendonitis, bursitis, and strain

Physiological demand:

- Predominantly aerobic; prolonged and performed at a low- to moderate-intensity

Qualitatively determined associated laboratory variables:

- Aerobic capacity
- Anaerobic power/ capacity
- Fat free mass
- Knee and trunk flexion and extension strength, shoulder internal and external rotation strength
- Shoulder external rotation flexibility
- Medicine ball toss, functional movement screen

Squad Attack: For this task, infantry carried roughly one hundred pounds for a half mile with their rifle and assault pack. Once they reached the obstacle, they climbed up to the top of it using a variety of techniques. A Marine would squat down with their back against the wall while another one stepped onto their knees and shoulders. The Marine who was standing on the person's knees and shoulders would then grab the edge of the box to climb up. The Marines who were last would jump up, grab the edge, and the other Marines who were already up on the obstacle would lean down and grab their arms in order to pull them up.

Specific movement patterns:

- 1 km Hike
  - Added weight of gear, size/shape of equipment, and terrain may cause suboptimal mechanics
- Negotiating Obstacle – several observed techniques
  - Assistant in squat position against wall (hip and knee flexion at approximately 90 degrees); Climber uses hip/ knee flexion/extension to step on assistant's thigh or shoulder; Shoulder elevation to reach top of wall
  - Assistant in squat position with trunk flexion to thighs for climber to step on trunk to reach for top of wall
  - Assistants on top of wall - use trunk/should and trunk flexion/ extension to lift climber to top of wall
  - Safe landing from wall requires proper mechanics to absorb ground reaction forces

Potential/resultant injury analysis:

- 1 km Hike
  - Overuse lower extremity injuries including stress fractures patellofemoral pain syndrome, iliotibial band syndrome, shin splints, Achilles tendinopathy, plantar fasciitis
- Negotiating Obstacle
  - Cervical, thoracic, and lumbar spine injuries including muscular strains, disc injuries
  - Shoulder rotator cuff strain
  - Knee and ankle sprains, Achilles strain from jump landing

Physiological demand:

- 1 km Hike
  - Predominantly aerobic; longer duration activity at a low intensity
- Negotiating Obstacle
  - Anaerobic power and capacity; high intensity movement requiring quick bursts of power and power sustained over a period of time

Qualitatively determined associated laboratory variables:

- Anaerobic power/ capacity
- Aerobic capacity
- Anthropometrics (arm span, leg length)
- Knee flexion and extension strength
- Trunk flexion and extension strength
- Ankle inversion and eversion strength
- Dynamic postural stability
- Functional movement screen
- Standing broad jump

Tow Missile Shoot: 65 lb missile must be lifted, curled against the chest to load; shoot at targets 1600 and 1800 meters away.

Specific movement patterns:

- Tow Missile Shoot
    - Lower extremity squat, trunk flexion to extension and upper extremity stabilization to lift missile

Potential/resultant injury analysis:

- Tow Missile Shoot
    - Thoracic, lumbar, lower extremity and shoulder strains

Physiological demand:

- Tow Missile Shoot
    - Anaerobic power; short bursts of intense activity

Qualitatively determined associated laboratory variables:

- Anaerobic power/ capacity
- Knee flexion and extension strength
- Trunk flexion and extension strength
- Shoulder internal and external rotation strength
- Shoulder external rotation flexibility
- Medicine ball toss
- Functional Movement Screen

Mountain Warfare

~9.5 Kilometer Hike: Marines began with the hike with a pack that weighed approximately 71-75 lb. Most Marines used a similar technique to get the pack on their back. They would begin by squatting down with their pack resting on the ground. They would grab the shoulder straps and bring it to their knees. Once it was on their knees they would standup while flipping the pack over their head and onto their back. The hike began at an altitude of 6600 ft and increased to a peak of 7500 ft with terrain including gravel, dirt, paved road, roots, and mud. The hike is primarily aerobic due to the long duration and moderate intensity of the task.

Gorge Crossing: Upon completion of the hike, Marines were required to cross the gorge using a pre-existing rope set-up. After removing their packs, the Marines tied their Swiss seats using rope from their pack. To mount the rope, the Marine pulled the rope down and lifted their legs up, wrapping them around the rope allowing them to clip into the rope from their harness situated at their waist. After the Marine was securely clipped in, they would lower their legs adopting a supine position, legs hanging down, and head first toward the gorge. To begin the crossing, most Marines utilized the same hand-over-hand technique to move themselves towards the other side of the gorge. Due to the slack in the rope, the beginning portion of the crossing was downhill and easier for most Marines. As the Marines approached the middle, some Marines adopted a bicycle-kick technique and/or changing from the hand-over-hand technique to a two-handed approach, to provide the necessary momentum to complete the crossing. Dismounting was similar to mounting technique in reverse requiring the Marine to lift their legs and wrap them around the rope to allow them to unclip themselves from the rope, followed by lowering themselves to the ground. Marines crossed the gorge without their packs, requiring them to be sent separately after most of the Marines had crossed. To do so, the Marines on the beginning side would load packs onto the rope in groups of 5-6 and the Marines on the opposite end would pull them across using a hand-over-hand technique.

Rock Climbing: For this task, Marines had to scale a rock wall (randomly selected 1 of 2 lanes; both 5.7 level of difficulty on the Yosemite scale) and then repel back down. The Marines completed with task with no pack.

Notes:

- 2 lanes; 5.7 on the Yosemite scale
- Order is randomized to which lane they will traverse
- Climbing = 3-4 holds at a time
- Main movement from lower extremity
- Total knee and hip flexion to extension to lift body to next hand hold
- Boots require that their hips and knees are externally rotated

After compete the climb, they fully extend their knees and lean their upper body back to a standing position on the rock face and walk or jump down the rock face until they have reached the bottom

- Hands on helmet or out to the side to brace on ledges
- Leaning/sitting back in the harness
- Full body extension then flexion
- Opposite arm and leg moving constantly – quadruped position

Specific movement patterns:

- ~9.5 km hike
  - Lower extremity squat with pack on knee, bilateral shoulder flexion/external rotation to lift and flip pack over head as lower extremities extend to standing.
  - Added weight of gear, size/shape of equipment and variable terrain may cause suboptimal mechanics during hikes. Observed trunk forward lean position to adjust center of mass due to pack weight and lateral shifting to propel advancing lower extremity, particularly on inclined terrain. Observed males walking with shorter stride, greater toe out angle compared to females with same pace/ speed due to different physical characteristics (leg length, etc.). Compression and sheer forces through spine due to pack and gear weight.
- Gorge Crossing
  - Supine position while pulling across line over gorge
  - Shoulder flexion and extension, core activation, leg extension (varying techniques)
- Rock Climbing
  - Grip strength, extending arms and legs, pulling upward to ascent up rock
  - Descended rock with legs extended, arms behind head or away from rope

Potential/resultant injury analysis:

- Pack mounting
  - Potential for direct cervical/ spinal trauma when weight of pack makes contact with back, shoulder impingement, strains, and/or instability from flipping motion
- Ruck Marching
  - Cervical and lumbar spine injuries including muscular strains and disc injuries
  - Overuse lower extremity injuries including stress fractures, patellofemoral pain syndrome, iliotibial band syndrome, Achilles tendinopathy, shin splints, plantar fasciitis. Long-term risks of disc and lower extremity cartilage damage
  - Thoracic, lumbar, lower extremity and shoulder strains; knee and ankle sprains
- Gorge Crossing
  - Lower back pain from prolonged period suspended in supine position
  - Shoulder, thoracic, and lumbar strains
- Rock Climbing
  - Shoulder strain
  - Lower extremity injury from large degree of rotation/extension of legs
  - Bruises/abrasions from contact with rock

Physiological demand:

- ~9.5 km hike
  - Primarily aerobic capacity (prolonged duration) with use of anaerobic power/capacity during areas of increasing elevation
- Gorge Crossing and Rock Climbing
  - Anaerobic capacity
    - Intense activity lasting a few minutes

Qualitatively determined associated laboratory variables:

- Aerobic Capacity
- Shoulder internal & external rotation strength
- Torso flexion & extension strength
- Ankle inversion & eversion strength
- Ankle dorsiflexion flexibility and active knee extension flexibility
- Static balance and NeuroCom

Artillery

Firing the Howitzer: The task began with a Marine relaying the azimuth to everyone else. A Marine then grabbed a 95 pound howitzer round using a two hand carry technique and walked a few yards to the howitzer. The Marine inserted it into the chamber while slightly leaning forward and using their legs for assistance. Two Marines then used an approximately fifty pound pole to ram the round fully into the chamber. A Marine on the side of the howitzer leaned over and inserted a long circular tube behind the round in the chamber. Finally, a Marine attached a rope to the howitzer while the other end was attached to the hip. Left torso rotation was used to pull the firing pin to fire the howitzer. Once fired, the rope was removed from the howitzer.

Specific movement patterns:
- Knee, hip, and trunk flexion/extension, when lifting round
- Trunk flexion, lower extremity and shoulder stabilization, elbow extension while loading round
- Trunk and shoulder stabilization, reciprocal lower extremity rapid stepping while ramming round
- Left pelvic and torso rotation to pull firing pin

Potential/resultant injury analysis:
- Thoracic/ Lumbar strain, disc injury

Physiological demand:
- Anaerobic power and capacity; short bursts of quick movements and prolonged, high intensity activity

Qualitatively determined associated laboratory variables:
- Anaerobic power/ capacity
- Knee flexion and extension strength
- Torso rotation strength
- Trunk flexion and extension strength
- Shoulder internal and external rotation strength
- Medicine ball toss
- Functional movement screen

Moving the Howitzer: To move the Howitzer, a Marine used a wheel to lower the barrel of the Howitzer. Two Marines pumped levers using a push/pull method to elevate the spades. After that was completed, two Marines lifted the spades off the ground and into the upright position. The seven ton truck backed up towards the barrel of the howitzer and a tow attachment was placed on the truck as well as the howitzer. Marines walked or jogged one hundred yards to a new location. The howitzer was set into place by lowering the spades and then holes were dug for the spades. The howitzer was removed from the truck and the tow attachment was dismantled and placed back inside the seven ton.

Digging Holes: Eight Marines dug a hole for roughly twenty minutes. The hole must be deep enough for the Marines to take cover in and use their weapon.

Specific movement patterns:

- Pumping lever
  - Standing row (core and lower extremity stabilized, repetitive shoulder and elbow flexion/extension)
- Lifting howitzer
  - Dead lift mechanics for lifting howitzer
- Digging holes
  - Trunk, hip, knee, shoulder, elbow flexion/extension for digging holes

Potential/resultant injury analysis:

- Thoracic/ Lumbar stain
- Shoulder overuse injuries (rotator cuff tendonitis impingement, bicipital tendonitis)

Physiological demand:

- Anaerobic power and capacity; short bursts of quick movements and prolonged, high intensity activity

Qualitatively determined associated laboratory variables:

- Anaerobic capacity/ power
- Knee flexion and extension strength
- Shoulder internal and external rotation strength
- Functional movement screen
- Medicine ball toss
- Standing broad jump

Raising/Taking down the Canopy: To raise the canopy, two to four Marines climbed into the back of the seven ton and started to unravel the canopy. The canopy was then draped over the truck. Two Marines hammered the metal pipes into the ground while others climbed on the side of the truck to assist with the canopy. Two Marines used long poles to raise portions of the canopy, but once the poles were in place, the Marines would tie down the canopy to the poles. In order to take down the canopy, the Marines started by untying the ropes that held the canopy down. One Marine would remove the poles used to hold the canopy up while another Marine removed the short metal poles stuck in the ground. Four Marines then folded the canopy close to the truck and then rolled it towards the front of the truck. They then would lift the roll onto the back of the truck while the others put the poles away on the side of the truck.

Specific movement patterns:

- Pushing/pulling canopy up the truck
    - Squat with overhead press movements
    - Trunk flexion/extension with shoulder and elbow flexion
- Jumping off of the 7 ton
    - Shoulder extension with hip abduction to hip/knee flexion to extension to step on tire and then climb up
    - Safe descent requires proper landing mechanics including hip and knee flexion to absorb ground reaction forces.

Potential/resultant injury analysis:

- Thoracic/ Lumbar stain
- Upper extremity overuse injuries (rotator cuff tendonitis, impingement, bicipital tendonitis)
- Ankle and knee sprains from poor landing mechanics jumping from tank
- Long-term risks for lower extremity cartilage damage

Physiological demand:

- Anaerobic power and capacity; short bursts of quick movements and prolonged, high intensity activity

Qualitatively determined associated laboratory variables:

- Aerobic capacity
- Anaerobic power/ capacity
- Trunk flexion and extension strength
- Shoulder internal and external rotation strength
- Knee flexion and extension strength
- Ankle inversion and eversion strength
- Ankle dorsiflexion flexibility
- NeuroCom
- Dynamic Postural Stability Index
- Standing broad jump
- Functional Movement Screen

Elevating the Barrel: One Marine used his/her left arm to spin the wheel to elevate the howitzer barrel, which took around thirty to sixty seconds.

Elevating the Howitzer: Two Marines began by pumping levers to elevate the spades using a push/pull method. They then lifted the spades off the ground and into the upright position. Three Marines inserted a pole into the barrel of the howitzer and used their body weight by jumping on the pole to lift the back end of the howitzer off the ground. Once it was lifted off the ground, they pushed on the bar to turn the howitzer with the help of a fourth Marine. The howitzer was set down to measure where the spades were going to rest on the ground, and then it was lifted again so two Marines could dig holes for the spades. Once the holes were dug, the howitzer was set down and the spades were set into place and the pole is removed from the barrel.

Specific movement patterns:

- Pumping lever
  - o Standing row (core and lower extremity stabilized, repetitive shoulder and elbow flexion/extension)
- Lowering the pole
  - o Shoulder elevation to lateral pull-down movement
- Pushing the pole
  - o Quick, reciprocal lower extremity drive with core and upper extremity stabilized

Potential/resultant injury analysis:

- Thoracic/ Lumbar stain
- Upper extremity overuse injuries (rotator cuff tendonitis, impingement, bicipital tendonitis)
- Lower extremity muscle strains, possible knee and ankle sprains based on terrain

Physiological demand:

- Anaerobic power; short bursts of high intensity movements

Qualitatively determined associated laboratory variables:

- Anaerobic capacity/ power
- Knee flexion and extension strength
- Shoulder internal and external rotation strength
- Functional Movement Screen Medicine ball toss
- Standing broad jump

Combat Engineers

Loading Truck: For this task, a squad of Marines had to load thirty-two 155mm howitzer shells (95 lb) from the ground onto a truck with a bed height of approximately six feet. To pick up the shell, the Marine would tilt the shell, grab the bottom of the shell and bring it up to chest height. They then would use their knee to bump the shell up onto their shoulders. The shell then was passed to a Marine who was sitting on the truck bed with their legs hanging off. The Marine who was seated would pull the shell into their lap, then rotate their trunk to stand the shell up next to them. A third Marine who was standing in the truck would pick the shell up and set it in a pallet for transport.

Specific movement patterns:
- Lifting shells
  - Knee, hip, and trunk flexion to extension
  - Core stabilization and elbow flexion to secure shell on shoulder
  - Shoulder overhead press to lift shell
- Loading shells
  - Trunk flexion/extension and elbow flexion to pull shell onto lap
  - Core stabilization and trunk rotation to pass shell laterally

Potential/resultant injury analysis:
- Cervical, thoracic, lumbar muscular strains, disc injuries
- Shoulder rotator cuff strain and with repetition, shoulder overuse injuries (shoulder impingement, tendonitis, bursitis)

Physiological demand:
- Anaerobic power and capacity; short bursts and prolonged bouts of high intensity activity
- Aerobic capacity; prolonged task (endurance to load thirty-two shells)

Qualitatively determined associated laboratory variables:
- Aerobic capacity
- Anaerobic power/ capacity
- Knee flexion and extension strength
- Trunk flexion and extension strength
- Shoulder internal and external rotation strength
- Torso rotation strength
- Torso rotation flexibility
- Shoulder external rotation flexibility
- Functional Movement Screen
- Standing broad jump
- Medicine ball toss

Squad Attack: For this task, engineers carry roughly fifty-five pounds for a half mile with their rifle and Bangalore. Once they reached the obstacle, they climbed up to the top of it using a variety of techniques. A Marine would squat down with their back against the wall while another one stepped onto their knees and shoulders. The Marine who was standing on the person's knees and shoulders would then grab the edge of the box to climb up. The Marines who were last would jump up, grab the edge, and the other Marines who are already up on the obstacle would lean down and grab their arms in order to pull them up.

Specific movement patterns:

- 1 km Hike
  - Added weight of gear, size/shape of equipment and terrain may cause suboptimal mechanics
  - Observed trunk forward lean position to adjust center of mass due to pack weight and lateral shifting to propel advancing lower extremity, particularly on inclined terrain
  - Observed males walking with shorter stride, greater toe out angle compared to females with same pace/ speed due to different physical characteristics (leg length, etc.)
  - Compression and sheer forces through spine due to pack and gear weight
- Negotiating Obstacle
  - Assistant in squat position against wall (hip and knee flexion at approximately 90 degrees), while climber uses hip/ knee flexion/extension to step on assistant's thigh or shoulder; shoulder elevation reach for top of wall
  - Assistant in squat position with trunk flexion to thighs for climber to step on trunk to reach for top of wall
  - Assistants on top of wall - use trunk/shoulder flexion/ extension to lift climber to top of wall
  - Safe landing from Connex box requires proper mechanics to absorb ground reaction forces

Potential/resultant injury analysis:

- 1 km Hike
  - Overuse lower extremity injuries including stress fractures, patellofemoral pain syndrome, iliotibial band syndrome, shin splints, Achilles tendinopathy, plantar fasciitis with hiking
- Negotiating Obstacle
  - Cervical, thoracic, lumbar spine injuries including muscular strains, disc injuries
  - Shoulder rotator cuff strain
  - Knee and ankle sprains, Achilles strain from jump landing

Physiological demand:

- 1 km Hike
  - Predominantly aerobic; longer duration activity at a low intensity
- Negotiating Obstacle
  - Anaerobic power and capacity; high intensity movement requiring quick bursts of power and power sustained over a period of time

Qualitatively determined associated laboratory variables:

- Aerobic capacity
- Anaerobic power/ capacity
- Knee flexion and extension strength
- Trunk flexion and extension strength
- Ankle inversion and eversion strength
- Dynamic Postural Stability Index
- Functional Movement Screen
- Standing broad jump

Vehicles

Light Armored Vehicle (LAV)/Reconnaissance

Disassembly and assembly of main gun 25mm: Marines climbed up to the roof of the LAV and got into the LAV in their respective positions. Both Gunners (Left)/VC (Right) were seated. The gunner performed a seated reach motion in order to reach the left/right side of the receiver, feeder, and panel of the main gun and items were removed. Next the turret is manually traversed and elevated. The gunner traversed the turret and elevated the gun in order to take barrel out from the feeder (one of the most physically demanding task of the gunner). A gunner held the feeder with both hands and slightly lifted it and slid it on the rail toward the gunner seat. Once the feeder was all the way down, a gunner held it with both arms, put it on the right shoulder, and lifted it off from the receiver. Then the gunner fliped the feeder 90 degrees counterclockwise (so the gauge faces upward) and placed it on the tray between the gunner and VC. A gunner held the barrel with both hands in a half squat position and extended the trunk/hips to lift the barrel and side stepped to slide the barrel out from feeder. The whole process is reversed to mount the barrel.

Specific movement patterns:

- Climbing on roof of LAV
  - Marine flexes and/or abducts hip joint 90-120 degrees and/or 60-90 degrees accordingly which requires proper mobility at an ankle, knee, and hip joint and upper body strength to pull him/herself up.
- Disassembling Weapons System
  - Static position (lateral flexion and rotation of spine, shoulder flexion of approximately 90-120 degrees) held for approximately 1-5 minutes
  - Assistant in squat position with trunk flexion to thighs for climber to step on trunk to reach for top of wall
- Manually traverse turret and elevate gun
  - To traverse turret, cranks (horizontal shoulder ab/adduction with slight elbow flexion/extension) as quickly as possible in the transverse plane (like mixing bowl)
  - To elevate/depress the main gun, cranks (shoulder flexion/ extension with slight elbow flexion/extension) as quickly as possible in the sagittal plane
  - Muscular endurance of glenohumeral/ scapulothoracic (shoulder) also is required to stabilize shoulder joint, but this task fatigues forearm and grip muscles most quickly
  - Muscular endurance and strength (approximately 2-minutes)
- Remove and disassemble feeder
  - Task requires proper stabilization and mobility of the lumbopelvic joint and core (torso and back) as well as muscular endurance and mobility at the glenohumeral joint (shoulder)
  - Precise upper body strength/technique
- Barrel dismount from feeder
  - While holding barrel in both hands, from half squat position, extend trunk/ hip to lift barrel and side step to slide barrel from feeder
- Mount feeder into receiver
  - Tasks require upper extremity and trunk movement in various planes including trunk rotation and UE chest press to mount feed
  - Proper lumbopelvic range of motion and stability, as well as, upper body strength and endurance are essential.
- Mount barrel back to the receiver
  - Deadlift and rotation of 109 lbs barrel

Potential/resultant injury analysis:

- Shoulder, lumbar, and lower extremity strains, disc injuries from lifting and lowering heavy weight.
- Shoulder overuse injuries including impingement, tendonitis, bursitis
- Upper extremity injuries from repetitive short range and fine motor movements such as shoulder impingement, biceps tendonitis, wrist flexor/ extensor strain, medial/ lateral epicondylitis, carpal tunnel syndrome
- As these task requires management of heavy equipment and machinery in a confined space, there is always risk of direct trauma resulting in fractures particularly of hand bones and lacerations

Physiological demand:

- Anaerobic power/capacity
  - Prolonged, moderate intensity activity and short bursts of high intensity activity
- Aerobic capacity
  - Task duration is prolonged (5-10 minutes to complete)

Qualitatively determined associated laboratory variables:

- Aerobic capacity
- Anaerobic capacity/ power
- Knee flexion and extension strength
- Trunk flexion and extension strength
- Shoulder internal and external rotation strength
- Torso rotation strength
- Ankle inversion and eversion strength
- Shoulder internal and external rotation, posterior capsule flexibility
- Active knee extension flexibility
- Ankle dorsiflexion flexibility
- Dynamic Postural Stability Index
- Static balance
- NeuroCom
- Functional Movement Screen Medicine ball toss
- Standing broad jump

Uploading ammunition to the LAV: This was a three crewman task: one was seated in the gunner seat while two picked up the ammunition can or dummy rounds and loaded them in through back door or side open hatch. Two Marines bent down to pick up the ammunition can (55lb, 40lb, 10-15lb) from the ground. From there, a Marine performed overhead lifting to upload the can through the side open hatch (approx. 5 ft) or a Marine would load it into the rear of the vehicle by picking up the dummy round/s, carry it across the shoulder and climb into the rear of the vehicle through the back door. A Marine at the gunner seat rotated their torso to accept the dummy rounds and drag them into the gunner/VC section using the slope. A Marine had to repetitively climb into and jump off from the back door of the LAV (approx. 25-30 inch).

Specific movement patterns:

- Holding ammunition
  - Hip/ knee flexion/ extension to squat, upper extremity and core stabilization
- Lifting ammunition
  - Overhead press
- Position ammunition
  - Crewman in gunner seat uses torso rotation to accept and position ammunition
- Repeated climbing up and jumping off of back door of LAV (approximately 25-30 inches)
  - Tricep extension with hip abduction to hip/knee flexion to extension to climb up
  - Safe landing requires proper mechanics to absorb ground reaction forces

Potential/resultant injury analysis:

- Thoracic, lumbar, and shoulder muscle strains
- Ankle and knee sprains/ injuries (ACL, meniscus, etc.), gastro- soleus strain from poor landing mechanics jumping from LAV
- Repetition can lead to overuse injuries such a tendonitis, bursitis, or cartilage damage
- Proper squat down technique/neutral spine required, or repetitive bending down without proper hip motion can lead to back problems
- Repetitive jumping from height without proper stabilization/biomechanics can increase risk of injury to the ankle, knee, and hip due to the repetitive impact

Physiological demand:

- Anaerobic power/capacity
  - Prolonged, moderate intensity activity and short bursts of high intensity activity
- Aerobic capacity
  - Task duration is prolonged (up to 20 minutes to complete)

Qualitatively determined associated laboratory variables:

- Anaerobic capacity/ power
- Aerobic capacity
- Torso rotation strength
- Shoulder internal and external rotation strength
- Torso rotation flexibility
- Dynamic Postural Stability Index
- Functional Movement Screen
- Medicine ball toss

Crew Evacuation: Three Marines were inside the LAV in their assigned positions. From there they exited their positions and climbed off the LAV and ran 30 yards to a cone.

Casualty Evacuation: The gunner and the driver start in their positions and the casualty is in the other gunner seat. The third gunner is off to the side and would step in if the task is not completed after 6 minutes. The two Marines exited their positions and one or both of the Marines lifted the casualty out of the gunner seat using a dead lifting motion. Then the casualty was moved from the gunner area towards the front of the LAV by dragging/carrying the casualty to the edge of the LAV. From here two methods were used. Method one: Fireman carry - the larger Marine would stand next to the LAV and the other Marine would assist in positioning the casualty on the Marine's shoulders. The Marine carrying the casualty would then walk 30 yards to a cone and the assisting Marine was carrying the rifles and pressing on the back of the casualty. Method two: two man carry - one Marine was on the LAV positioning the legs of the casualty on the second Marine's shoulders. The Marine held the legs and started to slide the casualty off of the LAV while the other Marine climbed down to get in to position to grab the casualty at the shoulders. They walked the casualty to the cone 30 yards away.

Specific movement patterns:

- Lifting dummy (casualty)
  - Observed crewman deadlifting casualty via cargo straps under armpits
- Lowering/carrying dummy (casualty)
  - Fireman's Carry- Crewman in slight trunk and hip flexion, possible shoulder elevation/external rotation to stabilize dummy while walking

Potential/resultant injury analysis:

- Most significantly, the forward flexed position and heavy lifting requirement of pulling the dummy from gunner position places the crewmembers at risk for lumbar and shoulder strains, and lumbar disc injuries.
- Risk of fall as working in different levels/ planes and balancing variable surfaces
- Various traumatic injuries could include spinal, upper or lower extremity fracture, concussion, contusions and lacerations.
- Cervical, lumbar, shoulder strain while carrying casualty

Physiological demand:

- Anaerobic power/capacity
  - Short bursts of high intensity activity lasting 3-10 minutes

Qualitatively determined associated laboratory variables:

- Anaerobic power/ capacity
- Knee flexion and extension strength
- Trunk flexion and extension strength
- Shoulder internal and external rotation strength
- Torso rotation strength
- Ankle inversion and eversion strength
- Dynamic Postural Stability Index
- Active knee extension flexibility
- Functional Movement Screen Medicine ball toss
- Standing broad jump

Towing: The task started with the Marines inside the LAV in their assigned positions. They exited the LAV and one Marine was tasked with grabbing the hook attachments off the LAV. There were two 75lb hooks that were removed from the side of the LAV. One was just about head height and the other was about mid torso in height. There were many methods used to remove the two hooks; some used an overhead lift and others climbed on the tire and removed it.

The Marines then attached a cable to the downed vehicle and had to lift a 150lb tow bar, from about shoulder height, off the LAV and brought it to the front of the vehicle and attached it underneath; this was a two Marine job. Two Marines began to attach the tow bar and were in a kneeling position using their legs to rest the bar on and helped to lift it to the correct height. From there, one Marine deadlifted the other end of the bar and attached it to the downed vehicle. The reverse process was used to dismount the tow bar and put everything back into position.

Specific movement patterns:
- Lifting and lowering heavy blocks and bars (75-150lb) from shoulder height or above
- Overhead press, deadlift, squat lift techniques utilized

Potential/resultant injury analysis:
- Shoulder, lumbar, and lower extremity strains, disc injuries from lifting and lowering heavy weight

Physiological demand:
- Anaerobic power/capacity
    - Prolonged, moderate intensity activity and short bursts of high intensity activity
- Aerobic capacity
    - Task duration is prolonged (10-15 minutes to complete)

Qualitatively determined associated laboratory variables:
- Aerobic capacity
- Anaerobic power/ capacity
- Knee flexion and extension strength
- Trunk flexion and extension strength
- Shoulder internal and external rotation strength
- Active knee extension flexibility
- Functional Movement Screen
- Medicine ball toss

Removing armor panels: Marines began behind the LAV. Two backdoor armor panels, each weighing 200 lb, were removed. There were two methods used. Method one: One Marine held the panel and another unscrewed it from the door. The Marine then squatted down to touch the panel to the ground and then put it back on the door. The panel was then screwed on and the same process was repeated for the second panel. Method two: Two Marines held the panel and the third unscrewed it from the door, and the two Maines lowered the panel to the ground using a squat position and returned it to the door. This task takes between 5-10 minutes. Next, they removed the two front armor panels. Each panel weighs 75 lb and is shaped like a triangle. One Marine unscrewed the panel while the other Marine was holding it. Once unscrewed, the panel was removed and the Marine lowered it to the ground via a squat motion and then lifted it back up and reattached it.

Specific movement patterns:
- Repetitive forearm supination/pronation with wrist stabilization to unscrew panels
- Upper extremity and core stabilization, eccentric control of hip and knee flexion to lower panel, reversal to lift

Potential/resultant injury analysis:
- Upper extremity injuries from repetitive short range and fine motor movements such as epicondylitis, carpal tunnel syndrome
- Lumbar, and lower extremity strains from lifting and lowering heavy weight

Physiological demand:
- Anaerobic power/capacity
    - Short bursts of high intensity activity lasting 5-10 minutes

Qualitatively determined associated laboratory variables:
- Anaerobic power/ capacity
- Aerobic capacity
- Knee flexion and extension strength
- Trunk flexion and extension strength
- Shoulder internal and external rotation strength
- Active knee extension flexibility
- Functional Movement Screen
- Medicine ball toss

Tire change: Two Marines removed a 175 lb tire from the side of the LAV. The tire was removed by one or two Marines by unscrewing the bolts and lifting it off the attachment and setting it down on the ground via a squat movement. After that, one Marine unscrewed the nuts on the tire that was to be changed while another Marine crawled under the LAV to position the jack. Many methods were used to unscrew the eight bolts. Sometimes a push/pull method was used sometimes the Marine would use the legs to loosen the bolts. From there, the tire was removed by either one or two Marines. It was slightly lifted off the LAV and set onto the ground and rolled out of the way. The second tire then was placed on the LAV and the bolts were tightened. The same tire was removed again in the same manner as previously stated and the original tire was placed back on and tightened. The discarded tire was lifted back onto the LAV (about shoulder height). The tire was lifted by two Marines using a squat motion. One Marine used their body as a platform for the tire to be rolled on/up and the other Marine slid it into place.

Specific movement patterns:
- Repeated squatting and lifting/lower of tire to either mounting height (few inches) or storage location (about shoulder height)
- Hip and knee flexion/extension, shoulder elevation and press to lift, reversal to lower

Potential/resultant injury analysis:
- Shoulder, lumbar, and lower extremity strains, disc injuries from lifting and lowering heavy weight

Physiological demand:
- Anaerobic power/capacity
    - Prolonged, moderate intensity activity and short bursts of high intensity activity
- Aerobic capacity
    - Task duration is prolonged (15-25 minutes to complete)

Qualitatively determined associated laboratory variables:
- Anaerobic power/ capacity
- Aerobic capacity
- Knee flexion and extension strength
- Trunk flexion and extension strength
- Shoulder internal and external rotation strength
- Active knee extension flexibility
- Functional Movement Screen
- Standing broad jump

M1A1 Tanks

Loading Tank: For this task, each Marine loaded twenty rounds each weighing approximately 75 lbs. A Marine walked ten to fifteen yards from the tank to the ammo crate to retrieve the rounds. The Marine carried the round with two hands over to the tank, and in order to transfer it to the Marine standing on the tank, then would bend down and thrust the round to head level. The Marine on the tank would bend down to retrieve it and perform torso rotation to the left in order to pass it to the tank loader. The tank loader would take the round at chest level and step down into the loading zone. In order to load the round into the turret, the Marine used overhead lifting as well as torso rotation.

Reloading Exercise: For this task, a shell must be loaded into the main gun of the tank by a single Marine in under seven seconds. The crewman inside the tank rotates their torso to the right to accept the shell into his left arm. After the shell is received, the Marine would flip it using their right arm while rotating to the left to load the main gun.

Specific movement patterns for the reloading exercise:
- Load shell (30-85 lb) into main gun; 7 second limit
  - Taller individuals often rotate torso to the right to accept the shell into left arm, use right arm to flip (right shoulder external to internal rotation with forearm supination to pronation, opposite for left upper extremity) while rotating trunk to the left to load the main gun
  - Shorter individuals may not flip the shell over, but instead swing it out in front of themselves, rotating torso with the weight of the shell at approximately center of mass, to load the main gun
  - The quick movements needed to lift a round from chest level to head level when loading the tank may induce fatigue during repetitive tasks
  - The movement is similar to a clean in weightlifting, which is a very difficult and powerful movement

Potential/resultant injury analysis:
- Thoracic, lumber, and shoulder muscle strains
- Due to confined space, weight of shell, time requirements of the task, risk of direct trauma resulting in fractures particularly of hand bones, lacerations, and contusions

Physiological demand:
- Anaerobic power/capacity
  - Short bursts of high intensity activity; repetitive nature

Qualitatively determined associated laboratory variables:
- Anaerobic power/ capacity
- Torso rotation strength
- Shoulder internal and external strength
- Shoulder internal and external rotation, and posterior capsule flexibility
- Torso rotation flexibility
- Medicine ball toss
- Functional Movement Screen

Crew Evacuation: Exit tank with weapon and sprint to cone

Casualty Evacuation: For this task, crewmembers worked together in order to pull a 200 lb dummy from the tank commander position in the vehicle. Two Marines standing on top of the turret leaned down into the turret and grab the straps of the casualty's flak jacket, and performed an upright row to bring the casualty out of the tank. The third crew member grabbed the casualty around the torso and walked backward to clear the rest of the body from the turret. The crew would slide the casualty off the turret and then two Marines jumped onto the ground while the third Marine drops the casualty down to them. Once the casualty is off of the tank, the Marines sprinted with it to a cone in the distance. . For a crew evacuation, all crewmembers exited the tank with their weapons and sprinted to a cone in the distance. In this task, crewmembers jumped off the tank from different heights ranging from five to eight feet.

Specific movement patterns:

- Crew Evacuation
  - Jumping from tank (height of approximately 5-8 ft) safe landing requires proper mechanics to absorb ground reaction forces
- Casualty Evacuation
  - Two crew members flex forward into the turret, grab the straps of the casualty's flak vest, and perform an upright row to lift dummy
  - Third crewmember grasps dummy around torso and uses trunk extension/ backwards walking to pull lower extremities from turret
  - To lower dummy to ground, two crewmembers jump to ground. When jumping from tank safe landing requires proper mechanics to absorb ground reaction forces
  - Third crewmember lowers dummy to ground crewmembers who use lower extremity, core and shoulder stabilization to receive

Potential/resultant injury analysis:

- Crew Evacuation
  - Due to urgency of this task and unstable terrain, risk of ankle and knee sprains/injuries (ACL, MCL, etc.), muscle strains (hamstrings, gastrocnemius-soleus) from poor landing mechanics and agility requirements.
  - With repetition can lead to overuse injuries such a tendonitis, bursitis, or cartilage damage
- Casualty Evacuation
  - Most significantly, the forward flexed position and heavy lifting requirement of pulling the dummy from turret places the crewmembers at risk for lumbar and shoulder strains, and lumbar disc injuries.
  - Observed a crewmember nearly fall from tank while completing this task- various traumatic injuries could include spinal, upper or lower extremity fracture, concussion, contusions and lacerations

Physiological demand:

- Anaerobic power/capacity
  - Prolonged, moderate intensity activity (up to five minutes) and short bursts of high intensity activity

Qualitatively determined associated laboratory variables:

- Anaerobic power/ capacity
- Knee and trunk flexion and extension strength
- Shoulder internal and external rotation strength
- Torso rotation strength and ankle inversion and eversion strength
- Active knee extension flexibility
- Dynamic Postural Stability Index
- Medicine ball toss
- Functional Movement Screen

Manual Turret Traverse: During a manual turret traverse, the turret is cranked from position nine to three, the main gun is lifted all the way and then lowered back down, and then the turret is cranked back from position three to nine. A single crew member completed this exercise. In order to traverse the turret, the Marine would use their right arm to crank a handle like a mixing bowl. Once the turret was moved, the main gun needed to be lifted and then lowered back down. For this task, the crew member would use their left arm to crank in the sagittal plane. Once the main gun was lifted and lowered back down, the crew member cranked the handle again with their right arm.

Specific movement patterns:

- Traverse turret
  - Right arm cranks (horizontal shoulder abduction/adduction with slight elbow flexion/extension) as quickly as possible in the transverse plane (like mixing bowl) for approximately 5 minutes
- Traverse main gun
  - Left arm cranks (shoulder flexion/ extension with slight elbow flexion/extension) as quickly as possible in the sagittal plane for approximately 1 minute
  - While muscular endurance of glenohumeral/ scapulothoracic (shoulder) is required to stabilize shoulder joint, this task fatigues forearm and grip muscles most quickly; crewmember use trunk sway to increase power

Potential/resultant injury analysis:

- Upper extremity injuries from repetitive short range and fine motor movements such as shoulder impingement, biceps tendonitis, wrist flexor/ extensor strain, medial/ lateral epicondylitis, carpal tunnel syndrome

Physiological demand:

- Anaerobic power/capacity
  - Prolonged, moderate intensity activity and short bursts of high intensity activity
- Aerobic capacity
  - Task duration is prolonged (6-10 minutes to complete)

Qualitatively determined associated laboratory variables:

- Aerobic capacity
- Anaerobic capacity/ power
- Shoulder internal and external rotation strength
- Shoulder internal and external rotation, and posterior capsule flexibility
- Functional Movement Screen Medicine ball toss

Track Changing: Crews of three people would work to replace a damaged track and then reattach it and travel past a cone. The track itself weighs approximately 1600-1800 pounds. Crews began by shoveling out a divot in front of the track to be changed before the event started. In order to access the track and roll wheels at the front of the tank, crew members would put their back to the access panel like a wall squat with their hands by their sides and push back and lift up. However, to access the track and roll wheels at the back of the tank, crew members faced the access panel with their hands by their sides and lifted, jiggled, and punched the panel until it opened. Once the panels were open, the crewmembers used tools to remove bolts, thread chains, and attach track jacks from several positions. The crew would complete the tasks by lying under the tank, squatting next to it, sitting cross legged facing the tank, as well as half squatting to support a length of the track or for a heavy tool. The Marines used various techniques in order to replace the damaged piece of track. They would perform rowing motions to loosen bolts, swing a sledgehammer like a golf club in order to replace bolts in the track, and support the track with their shoulders when it is being broken or reattached.

Specific movement patterns:

- Repetitive overhead pressing/lowering of tools (15-20 lbs)
- Climbing up and jumping off tank
    - Tricep extension with hip abduction to hip/knee flexion to extension to climb up
    - Safe landing requires proper mechanics to absorb ground reaction forces
- Side-lying under the tank, with the bottom arm supporting a tool and the top arm rotating the tool
- Full squat (as in duck walk position) while manipulating gear and tools
- Sitting cross legged facing the tank to manipulate gear and tools
- Half squat to support a length of track or heavy tool (knees and hips slightly flexed with full body weight pushing into the tank)
- Long-sit position combining upper extremity lateral-pull down and trunk extension to loosen bolts
- Repetitive shoulder internal/external rotation (20 degree range of motion) to pump hydraulic track spreader
- Adequate flexibility of hip, knee and ankle joints essential for preventing injuries with these tasks.

Potential/resultant injury analysis:

- Ankle and knee sprains/ injuries (ACL, meniscus, etc.) from poor landing mechanics jumping from tank.
- Lumbar strains and disc injury from poor mechanics and static positions
- Upper extremity injuries from repetitive short range and fine motor movements such as shoulder impingement, tendonitis, epicondylitis, carpal tunnel syndrome
- Long-term risks of disc and lower extremity cartilage damage
- As these task requires quick completion, management of heavy equipment and machinery, there is always risk of direct trauma resulting in fractures particularly of hand bones, lacerations, and contusions

Physiological demand:

- Anaerobic power/capacity
    - Short, high intensity movements followed by light activity

Qualitatively determined associated laboratory variables:

- Aerobic capacity
- Anaerobic power/ capacity
- Knee and trunk flexion and extension strength
- Shoulder internal and external and torso rotation strength
- Ankle inversion and eversion strength
- Flexibility (Shoulder internal and external rotation, active knee extension, ankle dorsiflexion)
- Postural Stability (Dynamic Postural Stability Index, NeuroCom)
- Functional Movement Screen Medicine ball toss
- Standing broad jump

Amphibious Assault Vehicle

Breaking/Reassembling track of AAV: The task began with all the Marines inside of the vehicle. The Marines then jumped out of the back door with either a single leg or double leg landing. Once outside of the vehicle, two Marines worked on unscrewing the bolts that connected the track shoe to the wheel. This was accomplished by having one Marine stand on the top of the track while holding the roof with both hands, as the other Marine kneeled down and unscrewed the bolt. The Marine who was standing on the top of the track was bouncing repetitively on it in order to make it easier to loosen the bolts. Two different Marines were working on unscrewing the bushing which stabilized the pin in the shoe of the track. In order to complete this task, one Marine was lying on their side under the vehicle unscrewing the bushing as the other Marine was half kneeing and using a large socket wrench to unscrew the bushing from the outside of the track. Once the bushing was loosened, a Marine swung a sledge hammer like a golf club in order to strike the bolt for a Marine under the vehicle to catch. After the pin was removed, a Marine stuck the inside of the track to break the track. This was completed by holding the sledge hammer sideways and striking the inside of the track with a golf swing that uses right torso rotation. Once they broke the track, they moved the vehicle forward until top part of the track was in the middle of the vehicle. They then moved backwards to the same position. In order to assemble the track, a Marine used force to lift the bottom track shoe with a metal pipe while another one set the clamp jack. A Marine who was kneeling down used a regular wrench to tighten a clamp jack while another Marine got under the vehicle, lying on their side, and supported the wrench with their bottom hand and they use their top hand to tighten. The driver moved the vehicle forward and the body of shoes popped back in together. The Marines then inserted the pin, and tightened the bushing.

Specific movement patterns:

- Jumping down approximately 30 inches from hatch with tools landing with either single or double legs
- Side-lying position while manipulating tools. Trunk and shoulder stabilization
- Kneeling/ half kneeling while performing chop-like movement in sagittal plane with trunk rotation or manipulating tools Full squat (as in duck walk position) while manipulating gear and tools
- Standing position while swinging sledge hammer like golf swing (Torso rotation, horizontal ab/adduction of shoulder with elbow extended)

Potential/resultant injury analysis:

- Risk of hip, knee, ankle sprains/injuries (ACL, MCL, etc.), particularly with single leg landing.
- Lumbar strains and disc injury from poor mechanics and static positions
- Upper extremity injuries from repetitive short range and fine motor movements such as shoulder impingement, tendonitis, epicondylitis, carpal tunnel syndrome
- Long-term risks of vertebral disc and lower extremity cartilage damage
- These tasks requires quick completion, management of heavy equipment and machinery, there is always risk of direct trauma resulting in fractures particularly of hand bones, lacerations, and contusions

Physiological demand:

- Anaerobic power/capacity
    - Short, high intensity movements followed by light activity

Qualitatively determined associated laboratory variables:

- Aerobic capacity
- Anaerobic power/ capacity
- Knee and trunk flexion and extension strength
- Shoulder internal and external and torso rotation strength
- Ankle inversion and eversion strength
- Flexibility Shoulder internal and external rotation, active knee extension, ankle dorsiflexion)
- Postural Stability (Dynamic Postural Stability Index, NeuroCom)
- Functional Movement Screen
- Medicine ball toss
- Standing broad jump

Manual Lifting of the back Ramp: The task began with the Marines opening the ramp. They then placed a pulley system on the ceiling in the rear of the vehicle and extended the pulley line to the ramp. Marines lifted the ramp with a split leg position in which their left leg was forward, and their body was facing the front of the vehicle. They were holding a bar with both hands to the right side of their body. They rotated the bar counterclockwise using predominately right and left shoulder extension, elbow flexion, and right torso rotation. A Marine continued to perform this motion for approximately two to three minutes depending on how fast they were. Once a Marine became tired, they started using more trunk flexion to rotate the bar instead of torso rotation, shoulder extension, and elbow flexion. Once the Marine was finished lifting the ramp all the way up, they locked the ramp and secured it.

Specific movement patterns:
- Once pulley attached, crewman stands in lunge position holding crank with both hands.
- Crank rotated counterclockwise using bilateral shoulder extension, elbow flexion, right torso rotation and hip/knee flexion/extension in lung position. Quick repetitions for 2-3 minutes
- With fatigue, observed trunk flexion/extension motion to rotate bar
- Task requires adequate stabilization and mobility of lumbopelvic joint, thoracic spine and upper body endurance

Potential/resultant injury analysis:
- Overuse shoulder injuries including tendonitis, bursitis
- Lumbar strain, disc injury

Physiological demand:
- Anaerobic power/capacity
    - Short, high intensity movements sustained for a few minutes

Qualitatively determined associated laboratory variables:
- Anaerobic capacity/ power
- Aerobic capacity
- Knee flexion and extension strength
- Trunk flexion and extension strength
- Shoulder internal and external rotation strength
- Torso rotation strength
- Medicine ball toss
- Functional Movement Screen

Mounting of the weapon system (External and Internal): For external mounting of the weapon system, a Marine bent down and picked up the machine gun with both hands from the ramp. They performed an overhead lift to the roof of the AAV. The Marine then climbed up to the roof and picked it up again in order to mount it to the turret. Internal mounting of the weapon system was very similar, with the exception that it was completed from inside of the vehicle. After the Marine picked up the machine gun while bending down, they climbed into the rear of the vehicle and stepped onto the gunner's seat. They performed an overhead lift and held that position while a Marine who was on the roof helped to mount it.

Specific movement patterns:

- External
  - Trunk flexion to pick up machine gun
  - Overhead press to lift machine gun to AAV roof
  - Various movement patterns to climb onto AAV
  - Repeat lift to mount on turret
- Internal
  - Similar to external but requires hip and knee flexion/extension to step onto gunner seat while using core and shoulder stabilization to hold machine gun and maintain balance
  - Overhead press to lift machine gun and static stabilization while another crewman assists with mounting.

Potential/resultant injury analysis:

- Thoracic, lumber, and shoulder muscle strains

Physiological demand:

- Anaerobic power/capacity
  - Short, high intensity movements sustained for a few minutes

Qualitatively determined associated laboratory variables:

- Anaerobic power/ capacity
- Trunk flexion and extension strength
- Shoulder internal and external rotation strength
- NeuroCom
- Medicine ball toss
- Functional Movement Screen

External/Internal Casualty Evacuation: In order to evacuate a casualty, two Marines climbed up to the roof of the AAV. One Marine got into a prone position and reached into the hatch to grab a casualty's flak jacket. The other Marine kneeled down and grabbed the casualty's arms and they both pulled them up together. Once the casualty's upper body was clear of the vehicle, a third Marine grabbed their torso and walked backward on top of the vehicle to clear the body. They then laid the person down on top of the roof to examine them. External casualty evacuation requires more strength compared to the internal evacuation which requires more technique.

Specific movement patterns (external casualty evacuation):
- First crewman, prone position reaching into hatch to grasp dummy's vest
- Upright row, trunk extension to lift while second crewman, in kneeling position, grabs dummy's arms to lift
- Third crewmember grasps dummy around torso and uses trunk extension/ backwards walking to pull lower extremities from turret
- Trunk, hip, knee flexion to lower dummy to supine position on roof
- Trunk flexion to pick up machine gun

Potential/resultant injury analysis:
- Most significantly, the forward flexed position and heavy lifting requirement of pulling the dummy from hatch places the crewmembers at risk for lumbar and shoulder strains, and lumbar disc injuries.
- Risk of fall as working in different levels/ planes and balancing variable surfaces- various traumatic injuries could include spinal, upper or lower extremity fracture, concussion, contusions and lacerations.

Physiological demand:
- Anaerobic power/capacity
  - Short, high intensity movements sustained for one to two minutes

Qualitatively determined associated laboratory variables:
- Anaerobic power/ capacity
- Knee flexion and extension strength
- Trunk flexion and extension strength
- Shoulder internal and external rotation strength
- Torso rotation strength
- Ankle inversion and eversion strength
- Active knee extension flexibility
- Dynamic Postural Stability Index
- Functional Movement Screen
- Medicine ball toss
- Standing broad jump

APPENDIX

Table 1. Pre-MOS Testing Completed JUL-AUG 2014

Location/Group	MOS	Females
SOI-E (Companies A and B)	0311	9
	0331	16
	0341	12
	0351	3
	0352	8
SOI-W (LAV/AAV)	1833	14
	0313	7
TOTAL		**68**

Table 2. Pre-GCE ITF Testing Completed as of 20 FEB 2015 by MOS and Gender

MOS	Total	Males	Females
0311	73	61	12
0313	16	11	5
0331	16	9	7
0341	23	16	7
0351	3	1	2
0352	17	13	4
1833	27	18	9
0811	31	18	13
1812	19	17	2
1371	24	16	8
PI	51	38	13
PM	9	6	3
TOTAL	**309**	**224**	**85**

Table 3. Interval Testing Completed as of 20 FEB 2015 by MOS and Gender

MOS	Total	Males	Females
0311	21	16	5
0313	3	2	1
0331	2	1	1
0341	4	4	0
0351	1	0	1
0352	2	2	0
1833	17	14	3
0811	19	11	8
1812	11	11	0
1371	11	7	4
PI	13	13	0
PM	0	0	0
TOTAL	**104**	**81**	**23**

Table 4. Post-Testing Completed as of 10 JUNE 2015 by MOS and Gender

MOS	Total	Males	Females
0311	6	6	0
0313	10	4	6
0331	4	0	4
0341	3	2	1
0351	0	0	0
0352	3	1	2
1833	6	3	3
0811	12	4	8
1812	13	11	2
1371	2	2	0
PI	6	3	3
PM	1	0	1
TOTAL	**66**	**36**	**30**

Table 5. Percentile Analysis: Assuming that a higher value is better

Variable	Number of males	Male 5th percentile	Proportion of females who are at or exceed the male 5th percentile value	95% CI for proportion
Height (in)	218	64.98	34/84 = 0.4048	0.2990, 0.5175
Shoulder Internal Rotation Strength – Stronger Side (N*m)	217	28.18	25/83 = 0.3012	0.2053, 0.4118
Shoulder Internal Rotation Strength – Weaker Side (N*m)	217	24.98	24/83 = 0.2892	0.1948, 0.3991
Shoulder External Rotation Strength – Stronger Side (N*m)	217	23.39	13/83 = 0.1566	0.0861, 0.2529
Shoulder External Rotation Strength – Weaker Side (N*m)	217	21.39	6/83 = 0.0723	0.0270, 0.1507
Knee Flexion Strength – Stronger Side (N*m)	216	61.75	57/83 = 0.6867	0.5756, 0.7841
Knee Flexion Strength – Weaker Side (N*m)	216	50.34	69/83 = 0.8313	0.7332, 0.9046
Knee Extension Strength – Stronger Side (N*m)	216	119.55	49/83 = 0.5904	0.4769, 0.6972
Knee Extension Strength – Weaker Side (N*m)	216	104.09	57/83 = 0.6867	05756, 0.7841
Trunk Flexion Strength (N*m)	214	98.35	56/83 = 0.6747	0.5630, 0.7735
Trunk Extension Strength (N*m)	214	155.18	40/83 = 0.4819	0.3708, 0.5944
Torso Rotation Strength – Stronger Side (N*m)	218	76.27	32/81 = 0.3951	0.2881, 0.5099
Torso Rotation Strength – Weaker Side (N*m)	218	66.49	50/81 = 0.6173	0.5026, 0.7231
Ankle Eversion Strength – Stronger Side (N)	218	20.89	72/83 = 0.8675	0.7752, 0.9319
Ankle Eversion Strength – Weaker Side (N)	218	18.33	71/83 = 0.8554	0.7611, 0.9230
Ankle Inversion Strength – Stronger Side (N)	217	17.06	74/83 = 0.8916	0.8041, 0.9492
Ankle Inversion Strength – Weaker Side (N)	217	15.33	75/83 = 0.9036	0.8189, 0.9575
Sensory Organization Test (SOT) Score	215	66.00	80/82 = 0.9756	0.9147, 0.9970
SOT Somatosensory Score	217	92.90	82/83 = 0.9880	0.9347, 0.9997
SOT Visual Score	217	67.00	77/83 = 0.9277	0.8493, 0.9730
SOT Vestibular Score	217	48.00	83/83 = 1.0000	0.9565, 1.0000*
Fat Free Mass (kg)	218	53.97	10/84 = 0.1190	0.0586, 0.2081
Abs Peak Anaerobic Power (W)	199	725.35	17/76 = 0.2237	0.1360, 0.3338
Abs Mean Anaerobic Capacity (W)	199	407.41	21/76 = 0.2763	0.1799, 0.3909
Abs VO2 Max (ml/min)	216	3177.56	10/82 = 0.1220	0.0601, 0.2129
Lactate Threshold (%VO2Max)	208	73.71	79/80 = 0.9875	0.9323, 0.9997
Arm Span (cm)	218	66.00	27/84 = 0.3214	0.2236, 0.4322
Left Leg Length (cm)	218	854.75	51/84 = 0.6071	0.4945, 0.7120
Right Leg Length (cm)	218	850.00	53/84 = 0.6310	0.5187, 0.7337
Sit and Reach (cm)	218	9.98	84/84 = 1.0000	0.9570, 1.0000*
Standing Broad Jump (cm)	218	164.92	40/83 = 0.4819	0.3708, 0.5944
Medicine Ball Toss (cm)	218	381.62	14/84 = 0.1667	0.0942, 0.2638
PFT Crunches (reps)	195	90.80	74/84 = 0.8810	0.7919, 0.9414

*one-sided, 97.5% confidence interval

Table 6. Percentile Analysis: Assuming that a lower value is better

Variable	Number of males	Male 95th percentile	Proportion of females who are at or below the male 95th percentile value	95% CI for proportion
Body Fat %	218	28.47	69/84 = 0.8214	0.7226, 0.8965
Agility Drill – Faster Side (sec)	218	6.04	44/83 = 0.5301	0.4174, 0.6407
Agility Drill – Slower Side (sec)	218	5.88	44/83 = 0.5301	0.4174, 0.6407
CFT Movement to Contact (sec)	210	324.00	43/84 = 0.5119	0.4004, 0.6226
CFT Maneuver Under Fire (sec)	210	256.45	30/84 = 0.3571	0.2555, 0.4692
PFT 3-mile Run (sec)	195	2563.60	73/84 = 0.8690	0.7778, 0.9328
Fat Mass (kg)	218	26.55	84/84 = 1.0000	0.9570, 1.0000*
Fight Load Index	218	1.01	25/84 = 0.2976	0.2027, 0.4073

*one-sided, 97.5% confidence interval

Table 7. Energy Intake and Expenditure - Calories (Mean ± SD)

	All (n=292)	Male (n=209)	Female (n=83)
Total Self-Reported Energy Intake	2274.2 ± 1619.8	2526.9 ± 1766.2	1683.1 ± 900.1
Total Energy Expenditure*	2621.9 ± 699.3	2682.6 ± 646.6	2469.2 ± 796.8

*Estimated by using the Cunningham equation and self-reported training habits

Table 8. Weight Goals and Energy Intake

	All (n=292)	Male (n=209)	Female (n=83)
Want to gain weight	***26%***	***28%***	***20%***
Percent Body Fat (Mean ± SD)	15.5% ± 5.5	14.5 ± 5.0%	20.9 ± 4.4%
Calorie Intake (Mean ± SD)	2,713.3 ± 1,561.7	2,966.6 ± 1,613.7	1,849 ± 988.6
Consuming excess calories for weight gain	48%	55%	24%
Consuming adequate calories to maintain weight	13%	14%	12%
NOT consuming adequate calories to meet needs	39%	31%	65%
Want to lose weight	***43%***	***41%***	***48%***
Percent Body Fat (Mean ± SD)	24.1% ± 4.9	22.6 ± 4.7%	27.5 ± 3.5%
Calorie Intake (Mean ± SD)	1,937.0 ± 1,227.1	2,166.3 ± 1,350.5	1,444.0 ± 697.3
Consuming adequate calories for weight loss	71%	66%	80%
Consuming adequate calories to maintain weight	9%	7%	13%
Consuming excess calories	21%	27%	8%
Want to maintain current weight	***38%***	***31%***	***31%***
Percent Body Fat (Mean ± SD)	19.0% ± 5.5	17.7 ± 5.4%	22.0 ± 4.5%
Calorie Intake (Mean ± SD)	2,379.2 ± 2,021.1	2,611.5 ± 2,255.7	1,798.4 ± 1,089.0
Consuming adequate calories to maintain weight	11%	11%	12%
Consuming excess calories	25%	29%	15%
NOT consuming adequate calories to meet needs	64%	60%	73%

Table 9. Carbohydrate Intake (Mean ± SD)

	All (n=292)	Male (n=209)	Female (n=83)
Carbohydrates (g)	245.4 ± 187.0	281.2 ± 204.5	187.1 ±107.1
Carbohydrates (g/kg body weight)	3.4 ± 2.5	3.6 ± 2.7	2.9 ± 1.7
Percent of calories from carbohydrate	45.8 ± 13.9	44.7 ± 13.1	48.5 ± 15.3

Table 10. Carbohydrate Intake Relative to Self-Report Exercise Volume

MET Hour/Week	N = 292 (% of ALL)	N = 209 (% of Male)	N = 83 (% of Female)	CHO Rec. (g/kg body weight)	All % Met	Male % Met	Female % Met
Low (< 10)	186 (64%)	147 (70%)	39 (47%)	3-5	27%	28%	26%
Moderate (10 - < 25)	83 (28%)	52 (25%)	31 (37%)	5-7	13%	15%	10%
High (≥ 25)	23 (8%)	10 (5%)	13 (16%)	6-10	13%	20%	8%

Table 11. Carbohydrate Requirements for Physical Training

Carbohydrate Requirements for Physical Training	All (n=292)	Male (n=209)	Female (n=83)
Met or exceeded the amount of carbohydrate in a typical US Diet (3-5 g/kg body weight/day)	46%	49%	36%
Met or exceeded the recommended amount of carbohydrate for general training needs (5-7 g/kg body weight/day)	19%	22%	12%

Table 12. Protein Intake (Mean ± SD)

	All (n=292)	Male (n=209)	Female (n=83)
Protein (g)	105.7 ± 71.7	115.2 ± 76.7	81.7 ± 49.8
Protein (g/kg body weight)	1.4 ± 1.0	1.5 ± 1.0	1.3 ± 0.8
Percent of calories from protein	19.4 ± 7.8	19.2 ± 7.5	19.7 ± 8.4

Table 13. Protein Requirements for Increasing Muscular Strength and Endurance

Protein Requirements for Increasing Muscular Strength and Endurance	All (n=292)	Male (n=209)	Female (n=83)
Fell within recommended protein requirements (1.2-1.7g/kg bw/day)	18%	19%	18%
Fell below recommended range for protein requirements <1.2 g/kg bw/day	51%	50%	52%
Exceeded recommended range for protein requirements (>1.8 g/kg bw/day)	26%	28%	22%

Protein Requirements for Increasing Muscular Strength and Endurance	All (n=292)	Male (n=209)	Female (n=83)
Met protein requirements, exceeded estimated energy needs	4%	5%	4%
Met/exceeded protein needs, did NOT meet estimated energy needs	30%	28%	35%
Fell below recommended protein range, did NOT consume adequate calories	51%	50%	52%

Table 14. Fat Intake

	All (n=292)	Male (n=209)	Female (n=83)
Fat (g)	90.5 ± 76.2	101.0 ± 83.7	63.8 ± 42.6
Fat (g/kg body weight)	1.2 ± 1.0	1.3 ± 1.1	1.0 ± 0.7
Percent of calories from fat	34.4 ± 10.9	35.1 ± 10.3	32.8 ± 12.1

Table 15. Distribution of Fat in the Diet

Distribution of Fat in the Diet	All (n=292)	Male (n=209)	Female (n=83)
Consumed within recommended range for fat intake (0.8g to ≤ 2.0g/kg/day)	51%	37%	34%
Consumed less than 0.8g fat per kg body weight/day	36%	33%	7%
Exceeded 2.0g fat per kg body weight/day	13%	15%	7%
Exceeded estimated energy requirements w/ highest fat consumption	14% (1.0-10.4g fat/kg)	17% (1.0-10.4g fat/kg)	6% (1.6-3.5g fat/kg)

Distribution of Fat in the Diet	All (n=292)	Male (n=209)	Female (n=83)
Consumed greater than 30% of calories from fat	71%	70%	72%
Consumed greater than 10% of calories from saturated fat	64%	72%	65%

Table 16. Fluids Consumed Before, During, and After Physical Training

Consumed Fluids	All (n=303)	Male (n=218)	Female (n=85)
Before Physical Training	79%	79%	78%%
During Physical Training	49%	50%	11%
After Physical Training	100%	100%	100%

Table 17. Types of Fluids Consumed

Type of Fluids Before PT	All (n=303)	Male (n=218)	Female (n=85)
Water	89%	88%	86%
Sports Drinks	5%	7%	3%
Other	7%	7%	11%

Fluids During PT	All (n=303)	Male (n=218)	Female (n=85)
Water	96%	96%	100%
Sports Drinks	3%	3%	1%
Other	1%	1%	1%

Fluids After PT	All (n=303)	Male (n=218)	Female (n=85)
Water	77%	76%	78%%
Sports Drinks	13%	15%	10%
Other	10%	9%	12%

Table 18. Timing and Content of Pre-Training and Post-Training Snack/Meal

Timing and Content of Pre-Training Snack/Meal	All (n=309)	Male (n=224)	Female (n=85)
Consumed pre-training meal or snack	40%	35%	53%
Pre-Training Type of Snack/Meal			
Contained both carbohydrate and protein	72%	74%	69%
Contained only protein	7%	8%	4%
Contained only carbohydrate	21%	18%	27%

Timing of Pre-Training Snack/Meal	All (n=309)	Male (n=224)	Female (n=85)
Less than 30 minutes prior to PT	16%	13%	19%
Between 30 minutes to 1 hour prior to PT	51%	54%	48%
1-2 hours prior to PT	22%	23%	23%
2-3 hours prior to PT	3%	4%	2%
3-4 hours prior to PT	2%	4%	0%

Timing and Content of Post-Training Snack/Meal	All (n=309)	Male (n=224)	Female (n=85)
Consumed post-training snack/meal	90%	100%	92%
Post-Training Type of Snack/Meal			
Contained both carbohydrate and protein	72%	75%	70%
Contained only protein	16%	16%	16%
Contained only carbohydrate	13%	12%	13%

Timing of Post-Training Snack/Meal	All (n=309)	Male (n=224)	Female (n=85)
Consumed a recovery snack/meal less than 30 minutes following PT	38%	46%	49%
Between 30 minutes to 1 hour following PT	48%	59%	44%
1-2 hours following PT	9%	12%	2%
2-3 hours following PT	2%	3%	2%
3-4 hours following PT	1%	3%	2%

Table 19. Diet Quality (Healthy Eating Index)

Marines Diet Quality				
HEI Component	**Mean ± SD**			**Max Score Possible**
	All (n=289)	**Male (n=206)**	**Female (n=83)**	
Adequacy (higher score = HIGHER consumption)				
Total Vegetable	3.0 ± 1.8	3.0 ± 1.8	3.2 ± 1.8	**5**
Green and Bean Vegetables	1.7 ± 2.2	1.6 ± 2.1	1.9 ± 2.2	**5**
Total Fruit	1.7 ± 2.0	1.7 ± 2.0	1.9 ± 2.1	**5**
Whole Fruit	1.5 ± 2.1	1.3 ± 2.0	1.8 ± 2.2	**5**
Whole Grain	1.7 ± 2.8	1.6 ± 2.7	2.2 ± 3.1	**10**
Total Dairy	5.2 ± 3.3	5.1 ± 3.3	5.3 ± 3.5	**10**
Total Protein	4.3 ± 1.3	4.4 ± 1.3	4.3 ± 1.4	**5**
Seafood and Plant Protein	1.4 ± 2.1	1.2 ± 2.0	1.9 ± 2.3	**5**
Fatty Acid Ratio	4.4 ± 3.3	4.2 ± 3.3	4.8 ± 3.4	**10**
Moderation (higher score = LOWER consumption)				
Sodium	2.6 ± 3.3	2.6 ± 3.2	2.8 ± 3.5	**10**
Refined Grains	6.3 ± 3.7	6.5 ± 3.5	5.8 ± 4.0	**10**
Empty Calories	11.8 ± 6.3	11.4 ± 6.3	12.7 ± 6.4	**20**
Total Score	45.6 ± 14.1	44.5 ± 13.4	48.4 ± 15.6	**100**

Table 20. Breakdown of Dietary Supplements Reported

Breakdown of Dietary Supplements Reported	All	Male	Female
Whey/Protein Supplements	26%	31%	17%
Multivitamin/Minerals	13%	10%	20%
Fish Oil, Omega 3 FA, Antioxidants	15%	14%	17%
BCAA, Amino Acids	13%	14%	12%
Creatine	5%	5%	2%
Pre-workout (Jack 3D/C4 Nitric Oxide, NO Explode)	9%	10%	6%
Glucosamine, Chondroitin, Joint Stability	3%	1%	7%
Energy Drinks/Caffeine	3%	1%	7%
Herbal Supplements, Probiotics	3%	2%	6%
Carbohydrate Gels/Endurance	0%	0%	0%
Unavailable	3%	3%	1%
Weight Loss	5%	6%	4%
Testosterone Boosters	2%	3%	0%

Table 21. Comparison of MOS School Graduates versus Non-Graduates*

	Graduated MOS School		Did Not Graduate*		K-W Test
	Median	**IQR**	**Median**	**IQR**	**p-value**
Right Ankle Eversion Strength (%BW)	35.23	30.85 , 39.52	30.98	27.51 , 35.90	0.024
Absolute Right Ankle Eversion Strength (N)	22.25	18.60 , 25.32	19.40	15.48 , 22.08	0.029
Left Ankle Eversion Strength (%BW)	34.48	31.86 , 40.35	30.22	26.31 , 34.41	0.014
Absolute Left Ankle Eversion Strength (N)	21.60	18.45 , 25.85	19.50	16.15 , 21.70	0.028
Right Ankle Inversion Strength (%BW)	34.77	31.04 , 39.18	29.03	22.79 , 33.97	0.011
Absolute Right Ankle Inversion Strength (N)	21.40	18.90 , 26.10	18.5	14.15 , 21.95	0.015
Left Knee Valgus/Varus Angle at Initial Contact (°)	-0.29	-2.78 , 1.29	0.83	0.04 , 3.84	0.022
Mean Anaerobic Capacity (W/kg)	6.96	6.23 , 7.57	6.25	5.48 , 7.06	0.021
VO2 Max (ml/kg/min)	43.43	40.72, 45.29	41.49	37.45 , 43.14	0.023

*Excludes motivational drops (DOR)

IQR = Interquartile range

Distribution is not the same between groups; Kruskal-Wallis test utilized to determine significant differences between groups

Table 22. Comparison of predictor variables between injured and uninjured subjects (combined)

Predictor		Not Injured n	Not Injured mean	Not Injured SD	Not Injured median	Injured n	Injured mean	Injured SD	Injured median	**p-value**
Demographic	Age	146	22.6	2.8	22.0	75	22.5	2.5	22.0	0.711
	Height (in)	146	68.8	3.4	69.1	75	67.2	3.5	67.0	0.002
	Weight (kg)	146	78.3	12.4	78.5	75	72.6	11.8	70.5	0.001
Absolute Strength	Abs Shoulder Internal Rotation Strength - Stronger Side (N*m)	144	43.3	15.3	44.2	75	36.8	14.1	35.1	0.003
	Abs Shoulder Internal Rotation Strength - Weaker Side (N*m)	144	37.9	13.8	36.6	75	32.6	12.2	30.2	0.005
	Abs Shoulder External Rotation Strength - Stronger Side (N*m)	144	31.7	9.1	32.5	75	27.0	7.9	26.7	0.000
	Abs Shoulder External Rotation Strength - Weaker Side (N*m)	144	28.4	8.1	28.9	75	23.9	6.9	23.8	<.0001
	Abs Knee Flexion Strength - Stronger Side (N*m)	144	93.3	24.3	94.1	74	82.4	22.1	76.0	0.001
	Abs Knee Flexion Strength - Weaker Side (N*m)	144	85.4	23.0	87.2	74	75.7	21.6	68.1	0.003
	Abs Knee Extension Strength - Stronger Side (N*m)	144	175.1	45.9	176.7	74	156.3	43.8	152.0	0.004
	Abs Knee Extension Strength - Weaker Side (N*m)	144	160.1	44.8	158.4	74	142.2	41.2	135.8	0.005
	Abs Trunk Flexion Strength (N*m)	145	152.8	38.8	149.4	74	138.3	42.0	134.2	0.011
	Abs Trunk Extension Strength (N*m)	145	239.6	71.1	235.4	74	214.6	71.7	201.3	0.015
	Abs Torso Rotation Strength - Stronger Side (N*m)	144	108.9	33.9	108.5	75	101.6	31.0	94.1	0.120
	Abs Torso Rotation Strength - Weaker Side (N*m)	144	100.1	30.9	99.8	75	94.3	29.1	88.0	0.178
	Abs Ankle Eversion Strength - Stronger Side (kg)	146	29.8	6.7	29.3	74	27.7	5.6	27.2	0.017
	Abs Ankle Eversion Strength - Weaker Side (kg)	146	27.4	6.6	27.0	74	25.3	5.9	25.3	0.019
	Abs Ankle Inversion Strength - Stronger Side (kg)	145	25.9	6.4	24.9	75	23.9	5.4	23.6	0.022
	Abs Ankle Inversion Strength - Weaker Side (kg)	145	23.4	6.1	22.5	75	21.6	4.9	21.0	0.026

Strength ratio	Right Shoulder External/Internal Rotation Strength Ratio	144	0.8	0.1	0.8	73	0.8	0.1	0.7	0.888
	Left Shoulder External/Internal Rotation Strength Ratio	143	0.8	0.1	0.8	75	0.8	0.1	0.7	0.924
	Right Knee Flexion/Extension Strength Ratio	144	0.5	0.1	0.5	71	0.5	0.1	0.5	0.942
	Left Knee Flexion/Extension Strength Ratio	143	0.5	0.1	0.5	73	0.5	0.1	0.5	0.957
	Trunk Flexion/Extension Strength Ratio	145	1.6	0.3	1.5	74	1.6	0.3	1.5	0.599
	Right Ankle Eversion/Inversion Strength Ratio	145	1.2	0.2	1.2	73	1.2	0.2	1.2	0.784
	Left Ankle Eversion/Inversion Strength Ratio	142	1.2	0.2	1.2	74	1.2	0.3	1.1	0.672
Flexibility/ Range of motion	Shoulder External Rotation Flexibility - Greater Side (°)	146	108.5	8.9	109.2	75	108.6	8.9	109.7	0.882
	Shoulder External Rotation Flexibility - Lesser Side (°)	146	101.4	8.7	101.2	75	100.5	8.5	101.0	0.467
	Shoulder Internal Rotation Flexibility - Greater Side (°)	146	58.5	6.4	59.0	75	60.2	6.1	60.0	0.056
	Shoulder Internal Rotation Flexibility - Lesser Side (°)	146	52.2	6.6	52.0	75	53.3	5.6	53.3	0.219
	Posterior Shoulder Tightness Flexibility - Greater Side (°)	146	103.4	5.0	103.2	75	105.0	4.9	105.0	0.023
	Posterior Shoulder Tightness Flexibility - Lesser Side (°)	146	97.8	4.7	97.3	75	98.1	4.3	97.7	0.645
	Active Knee Extension (Hamstirng) Flexibility - Lesser Side (°)	146	24.5	11.6	25.3	75	25.0	11.4	23.7	0.759
	Active Knee Extension (Hamstirng) Flexibility - Greater Side (°)	146	19.7	10.4	19.5	75	19.4	10.5	18.3	0.879
	Ankle Dorsiflexion Flexibility - Greater Side (°)	146	13.8	4.8	14.3	75	13.3	5.0	13.0	0.461
	Ankle Dorsiflexion Flexibility - Lesser Side (°)	146	11.3	4.9	11.3	75	10.6	4.7	10.3	0.295
	Torso Rotation Flexibility - Greater Side (°)	144	76.4	13.9	73.5	74	76.9	11.6	75.0	0.793
	Torso Rotation Flexibility - Lesser Side (°)	144	68.8	13.6	68.2	74	69.9	12.5	68.8	0.559

Balance	Dynamic Postural Stability Index - Worse Side	144	0.4	0.0	0.4	74	0.4	0.0	0.4	0.982
	Dynamic Postural Stability Index - Better Side	144	0.3	0.0	0.3	74	0.3	0.0	0.4	0.746
	Sensory Organization Test (SOT) Score	143	78.2	5.4	79.0	74	77.7	5.7	77.5	0.525
	SOT - Somatosensory Score	145	97.6	2.8	98.0	74	98.3	2.1	99.0	0.052
	SOT - Visual Score	145	84.1	8.5	84.0	74	84.4	9.6	87.0	0.778
	SOT - Vestibular Score	145	69.1	9.7	71.0	74	68.4	10.1	69.0	0.647
	SOT - Preference Score	143	100.1	6.0	101.0	74	99.6	7.4	99.0	0.576
	Single Legged Balance (Eyes Open) - Worse Side (SD vGRF)	145	5.7	2.0	5.3	75	5.7	2.7	4.9	0.872
	Single Legged Balance (Eyes Open) - Better Side (SD vGRF)	145	4.7	1.5	4.3	75	4.6	1.9	4.3	0.486
	Single Legged Balance (Eyes Closed) - Worse Side (SD vGRF)	145	16.5	6.8	15.1	75	16.2	7.4	15.4	0.762
	Single Legged Balance (Eyes Closed) - Better Side (SD vGRF)	145	13.0	5.3	11.8	75	12.9	6.5	12.0	0.898
Lower extremity biomechanics	Hip Flexion at Initial Contact - Better Side (°)	143	32.4	7.0	33.2	74	32.0	7.2	32.4	0.637
	Hip Flexion at Initial Contact - Worse Side (°)	143	28.3	7.4	28.3	74	27.7	7.1	27.6	0.576
	Hip Adduction at Initial Contact - Higher Side (°)	143	-9.0	4.2	-8.8	74	-8.8	4.6	-8.4	0.680
	Hip Adduction at Initial Contact - Lower Side (°)	143	-13.1	3.9	-13.1	74	-12.9	4.5	-12.5	0.652
	Absolute Hip Adduction at Initial Contact - Higher Side (°)	143	13.1	3.9	13.1	74	12.9	4.5	12.5	0.652
	Absolute Hip Adduction at Initial Contact - Lower Side (°)	143	9.1	4.1	8.8	74	8.8	4.6	8.4	0.620
	Knee Flexion at Initial Contact - Better Side (°)	144	14.1	5.0	13.6	74	15.2	5.4	13.7	0.160
	Knee Flexion at Initial Contact - Worse Side (°)	144	10.0	4.6	9.5	74	11.4	5.6	10.8	0.052
	Knee Valgus/Varus at Initial Contact - Higher Side (°)	144	1.3	2.9	1.3	74	0.7	3.8	0.7	0.180
	Knee Valgus/Varus at Initial Contact - Lower Side (°)	144	-1.5	3.3	-1.2	74	-1.9	3.5	-1.7	0.454
	Maximal Knee Flexion - Better Side (°)	144	56.3	7.4	54.8	74	54.6	7.1	54.2	0.094
	Maximal Knee Flexion - Worse Side (°)	144	51.0	7.3	50.5	74	50.0	7.1	49.7	0.318
	Peak Vertical Ground Reaction Force - Worse Side (%BW)	144	439.5	67.0	431.6	74	452.5	94.3	450.2	0.240
	Peak Vertical Ground Reaction Force - Better Side (%BW)	144	397.7	57.7	398.7	74	406.0	77.2	405.8	0.369

Physiology	Body Fat (BOD POD) %	146	20.4	6.0	20.5	75	21.4	6.4	21.4	0.254
	Fat Free Mass (kg)	146	62.3	10.6	63.6	75	56.9	9.6	57.1	0.000
	Fat Mass (kg)	146	16.1	5.6	15.8	75	15.7	5.6	15.7	0.634
	Fight Load Index	146	0.9	0.2	0.8	75	0.9	0.2	0.9	0.003
	Abs Peak Anaerobic Power (W)	136	941.2	212.0	949.3	68	849.8	216.4	844.9	0.004
	Abs Mean Anaerobic Capacity (W)	136	547.0	146.3	552.4	68	487.6	142.6	479.8	0.006
	Abs VO2 Max (ml/min)	145	3770.9	683.4	3816.2	72	3400.4	671.0	3409.4	0.000
	Lactate Threshold (%VO2 Max)	141	83.7	5.8	83.3	70	84.7	5.5	84.4	0.225
Field tests	Functional Movement Screen (total score)	146	17.6	1.6	18.0	75	17.5	1.7	18.0	0.750
	Arm Span (cm)	146	70.2	4.2	70.9	75	68.3	4.3	68.5	0.001
	Left Leg Length (cm)	146	924.2	54.1	927.5	75	898.9	59.4	890.0	0.002
	Right Leg Length (cm)	146	925.2	54.2	930.0	75	899.8	60.6	895.0	0.002
	Sit and Reach (cm)	146	26.2	9.0	26.5	75	27.2	9.2	27.7	0.427
	Standing Broad Jump (cm)	146	193.1	28.7	193.5	74	178.9	28.3	176.5	0.001
	Medicine Ball Toss (cm)	146	463.3	93.9	467.0	75	422.3	94.7	421.7	0.003
	Agility Drill - Slower Side (sec)	146	5.6	0.4	5.6	74	5.8	0.4	5.8	0.001
	Agility Drill - Faster Side (sec)	146	5.5	0.4	5.5	74	5.7	0.4	5.7	0.001
	Body Fat (circumference) %	137	19.7	6.4	19.0	70	22.0	6.5	22.0	0.017
PFT and CFT	CFT Movement to Contact (sec)	143	283.0	40.1	300.0	74	300.3	37.4	310.5	0.002
	CFT Maneuver Under Fire (sec)	143	241.0	42.5	231.0	74	254.4	44.2	240.5	0.031
	PFT Crunches (rep)	138	98.6	5.0	100.0	70	97.7	6.3	100.0	0.262
	PFT 3-Mile Run (sec)	138	2239.7	220.4	2226.5	70	2304.1	245.2	2288.5	0.057

Table 23. Comparison of predictor variables between injured and uninjured subjects (male Marines)

Predictor		Not Injured n	Not Injured mean	Not Injured SD	Not Injured median	Injured n	Injured mean	Injured SD	Injured median	p-value
Demographic	Age	111	22.5	2.7	22.0	41	22.6	2.6	22.0	0.893
	Height (in)	111	70.0	2.6	70.3	41	69.6	2.6	70.3	0.325
	Weight (kg	111	82.5	10.7	82.6	41	79.7	10.2	78.0	0.143
Absolute Strength	Abs Shoulder Internal Rotation Strength - Stronger Side (N*m)	110	48.8	12.9	47.7	41	46.9	11.0	44.8	0.400
	Abs Shoulder Internal Rotation Strength - Weaker Side (N*m)	110	42.7	12.0	40.8	41	40.8	10.3	38.6	0.371
	Abs Shoulder External Rotation Strength - Stronger Side (N*m)	110	35.4	7.0	35.2	41	32.9	5.4	32.8	0.045
	Abs Shoulder External Rotation Strength - Weaker Side (N*m)	110	31.6	6.2	31.3	41	29.1	4.7	27.8	0.017
	Abs Knee Flexion Strength - Stronger Side (N*m)	110	101.2	21.1	100.9	40	95.6	20.6	95.5	0.146
	Abs Knee Flexion Strength - Weaker Side (N*m)	110	92.4	20.4	92.3	40	87.5	22.1	89.5	0.202
	Abs Knee Extension Strength - Stronger Side (N*m)	110	190.4	39.9	188.3	40	181.6	40.2	177.6	0.235
	Abs Knee Extension Strength - Weaker Side (N*m)	110	174.1	39.9	172.1	40	164.9	40.0	162.5	0.214
	Abs Trunk Flexion Strength (N*m)	111	165.9	33.8	159.7	40	164.4	37.5	162.5	0.810
	Abs Trunk Extension Strength (N*m)	111	260.1	64.8	251.1	40	261.0	60.9	270.9	0.941
	Abs Torso Rotation Strength - Stronger Side (N*m)	111	119.0	30.2	114.6	41	121.4	25.3	123.1	0.650
	Abs Torso Rotation Strength - Weaker Side (N*m)	111	109.3	27.7	106.6	41	112.7	23.7	112.1	0.481
	Abs Ankle Eversion Strength - Stronger Side (kg)	111	30.8	6.8	30.0	41	28.6	4.9	28.3	0.060
	Abs Ankle Eversion Strength - Weaker Side (kg)	111	28.4	6.4	28.0	41	26.1	5.4	25.9	0.044
	Abs Ankle Inversion Strength - Stronger Side (kg)	110	26.8	6.3	25.6	41	24.3	5.5	24.0	0.025
	Abs Ankle Inversion Strength - Weaker Side (kg)	110	24.1	6.2	23.4	41	21.8	5.1	21.2	0.034

Strength ratio	Right Shoulder External/Internal Rotation Strength Ratio	110	0.8	0.1	0.7	41	0.7	0.1	0.7	0.290
	Left Shoulder External/Internal Rotation Strength Ratio	109	0.8	0.1	0.7	41	0.7	0.1	0.7	0.310
	Right Knee Flexion/Extension Strength Ratio	110	0.5	0.1	0.5	37	0.5	0.1	0.5	0.753
	Left Knee Flexion/Extension Strength Ratio	109	0.5	0.1	0.5	40	0.5	0.1	0.5	0.547
	Trunk Flexion/Extension Strength Ratio	111	1.6	0.3	1.5	40	1.6	0.2	1.6	0.678
	Right Ankle Eversion/Inversion Strength Ratio	110	1.2	0.2	1.2	41	1.2	0.3	1.2	0.602
	Left Ankle Eversion/Inversion Strength Ratio	108	1.2	0.2	1.1	41	1.2	0.3	1.2	0.160
Flexibility/ Range of motion	Shoulder External Rotation Flexibility - Greater Side (°)	111	108.1	9.2	109.3	41	106.3	7.9	108.3	0.256
	Shoulder External Rotation Flexibility - Lesser Side (°)	111	100.7	8.9	100.7	41	98.6	8.2	100.0	0.183
	Shoulder Internal Rotation Flexibility - Greater Side (°)	111	58.2	6.0	59.0	41	59.8	5.9	60.3	0.157
	Shoulder Internal Rotation Flexibility - Lesser Side (°)	111	51.8	6.7	51.7	41	52.7	5.8	53.0	0.418
	Posterior Shoulder Tightness Flexibility - Greater Side (°)	111	103.1	5.1	102.7	41	103.8	4.7	104.3	0.446
	Posterior Shoulder Tightness Flexibility - Lesser Side (°)	111	97.9	4.9	97.3	41	97.3	4.0	97.3	0.504
	Active Knee Extension (Hamstring) Flexibility - Lesser Side (°)	111	26.8	10.9	27.7	41	29.2	11.2	28.3	0.236
	Active Knee Extension (Hamstring) Flexibility - Greater Side (°)	111	21.9	9.9	23.0	41	23.7	10.5	22.3	0.313
	Ankle Dorsiflexion Flexibility - Greater Side (°)	111	13.5	4.7	14.0	41	12.7	5.3	12.7	0.384
	Ankle Dorsiflexion Flexibility - Lesser Side (°)	111	11.2	4.9	11.3	41	9.7	4.9	10.0	0.108
	Torso Rotation Flexibility - Greater Side (°)	111	75.6	14.2	73.3	40	78.2	11.6	79.2	0.307
	Torso Rotation Flexibility - Lesser Side (°)	111	68.4	13.9	67.0	40	72.2	12.4	71.8	0.128

Balance	Dynamic Postural Stability Index - Worse Side	109	0.4	0.0	0.4	41	0.4	0.0	0.4	0.459
	Dynamic Postural Stability Index - Better Side	109	0.4	0.0	0.4	41	0.4	0.0	0.4	0.831
	Sensory Organization Test (SOT) Score	109	78.0	5.4	79.0	41	77.2	5.5	77.0	0.424
	SOT - Somatosensory Score	110	97.7	2.6	98.0	41	98.3	1.9	99.0	0.178
	SOT - Visual Score	110	83.8	8.6	84.0	41	84.9	8.1	87.0	0.471
	SOT - Vestibular Score	110	68.8	9.7	71.0	41	67.5	10.1	69.0	0.481
	SOT - Preference Score	109	100.4	6.2	101.0	41	99.1	8.8	97.0	0.299
	Single Legged Balance (Eyes Open) - Worse Side (SD vGRF)	110	6.1	1.9	5.8	41	6.3	3.0	5.3	0.629
	Single Legged Balance (Eyes Open) - Better Side (SD vGRF)	110	5.1	1.5	4.9	41	5.1	2.0	4.6	0.920
	Single Legged Balance (Eyes Closed) - Worse Side (SD vGRF)	110	17.7	6.8	15.7	41	19.4	7.6	17.6	0.190
	Single Legged Balance (Eyes Closed) - Better Side (SD vGRF)	110	14.0	5.3	12.7	41	15.0	7.2	13.8	0.384
Lower extremity biomechanics	Hip Flexion at Initial Contact - Better Side (°)	109	31.2	6.2	31.0	41	30.3	7.5	29.3	0.453
	Hip Flexion at Initial Contact - Worse Side (°)	109	26.9	6.7	26.6	41	25.8	7.2	24.4	0.401
	Hip Adduction at Initial Contact - Higher Side (°)	109	-9.3	4.2	-9.2	41	-9.8	4.6	-9.3	0.505
	Hip Adduction at Initial Contact - Lower Side (°)	109	-13.4	3.9	-12.8	41	-13.6	4.7	-13.3	0.755
	Absolute Hip Adduction at Initial Contact - Higher Side (°)	109	13.4	3.9	12.8	41	13.6	4.7	13.3	0.755
	Absolute Hip Adduction at Initial Contact - Lower Side (°)	109	9.3	4.2	9.2	41	9.8	4.6	9.3	0.505
	Knee Flexion at Initial Contact - Better Side (°)	109	13.4	5.0	12.7	41	14.5	5.5	12.8	0.253
	Knee Flexion at Initial Contact - Worse Side (°)	109	9.3	4.5	8.9	41	10.3	5.9	9.4	0.277
	Knee Valgus/Varus at Initial Contact - Higher Side (°)	109	1.6	2.8	1.4	41	1.4	3.2	1.3	0.679
	Knee Valgus/Varus at Initial Contact - Lower Side (°)	109	-1.3	3.3	-1.1	41	-1.7	3.5	-0.8	0.497
	Maximal Knee Flexion - Better Side (°)	109	56.0	7.3	54.6	41	53.9	6.8	53.0	0.108
	Maximal Knee Flexion - Worse Side (°)	109	50.4	7.3	49.8	41	49.0	7.2	49.5	0.286
	Peak Vertical Ground Reaction Force - Worse Side (%BW)	109	442.4	69.0	431.2	41	479.6	100.9	460.7	0.011
	Peak Vertical Ground Reaction Force - Better Side (%BW)	109	400.5	59.6	400.5	41	420.5	78.2	417.8	0.095

Physiology	Body Fat (BOD POD) %	111	19.1	5.9	18.9	41	19.3	6.4	19.6	0.843
	Fat Free Mass (kg)	111	66.5	8.0	65.5	41	63.9	6.2	64.2	0.058
	Fat Mass (kg)	111	16.0	6.1	15.2	41	15.8	6.5	15.5	0.846
	Fight Load Index	111	0.8	0.1	0.8	41	0.8	0.1	0.8	0.257
	Abs Peak Anaerobic Power (W)	103	1020.2	174.1	1023.8	38	993.4	175.4	958.0	0.420
	Abs Mean Anaerobic Capacity (W)	103	602.4	117.8	601.9	38	579.1	109.4	577.5	0.290
	Abs VO2 Max (ml/min)	110	4035.7	535.0	3952.9	40	3868.3	465.7	3779.4	0.082
	Lactate Threshold (%VO2 Max)	107	83.9	6.0	83.8	39	83.4	5.4	82.6	0.611
Field tests	Functional Movement Screen (total score)	111	17.4	1.6	17.0	41	17.1	2.1	17.0	0.411
	Arm Span (cm)	111	71.9	3.1	72.0	41	71.2	3.1	71.1	0.221
	Left Leg Length (cm)	111	942.5	45.5	950.0	41	933.6	51.6	935.0	0.308
	Right Leg Length (cm)	111	943.5	45.5	950.0	41	935.3	52.4	935.0	0.348
	Sit and Reach (cm)	111	24.3	8.6	24.2	41	23.7	8.7	23.0	0.726
	Standing Broad Jump (cm)	111	202.7	23.8	201.7	41	194.2	23.2	195.3	0.050
	Medicine Ball Toss (cm)	111	502.1	68.8	497.3	41	494.2	61.4	486.7	0.520
	Agility Drill - Slower Side (sec)	111	5.5	0.3	5.5	41	5.5	0.3	5.5	0.256
	Agility Drill - Faster Side (sec)	111	5.4	0.3	5.4	41	5.4	0.3	5.4	0.263
	Body Fat (circumference) %	103	16.9	4.4	17.0	37	17.3	4.4	18.0	0.627
PFT and CFT	CFT Movement to Contact (sec)	108	269.9	34.6	252.5	40	278.7	33.3	279.0	0.171
	CFT Maneuver Under Fire (sec)	108	224.9	28.9	223.0	40	229.4	25.4	230.0	0.385
	PFT Crunches (rep)	103	99.1	4.5	100.0	36	98.5	5.0	100.0	0.506
	PFT 3-Mile Run (sec)	103	2210.5	213.3	2210.0	36	2221.0	241.9	2179.0	0.806

Table 24. Comparison of predictor variables between injured and uninjured subjects (female Marines)

Predictor		Not Injured n	Not Injured mean	Not Injured SD	Not Injured median	Injured n	Injured mean	Injured SD	Injured median	p-value
Demographic	Age	35	22.9	3.1	22.0	34	22.3	2.4	22.0	0.388
	Height (in)	35	64.8	2.2	64.5	34	64.4	2.1	64.4	0.431
	Weight (kg)	35	65.1	7.2	63.6	34	64.1	7.2	64.4	0.551
Absolute Strength	Abs Shoulder Internal Rotation Strength - Stronger Side (N*m)	34	25.4	6.0	25.1	34	24.7	4.8	23.3	0.583
	Abs Shoulder Internal Rotation Strength - Weaker Side (N*m)	34	22.5	5.3	21.5	34	22.7	4.6	21.9	0.839
	Abs Shoulder External Rotation Strength - Stronger Side (N*m)	34	19.9	2.8	20.1	34	20.0	3.2	19.7	0.968
	Abs Shoulder External Rotation Strength - Weaker Side (N*m)	34	17.7	2.4	18.1	34	17.6	2.5	17.4	0.868
	Abs Knee Flexion Strength - Stronger Side (N*m)	34	67.9	14.9	66.5	34	67.0	11.2	68.2	0.787
	Abs Knee Flexion Strength - Weaker Side (N*m)	34	63.0	15.5	64.1	34	61.9	9.6	62.0	0.731
	Abs Knee Extension Strength - Stronger Side (N*m)	34	125.5	23.6	123.6	34	126.4	25.2	122.2	0.878
	Abs Knee Extension Strength - Weaker Side (N*m)	34	114.6	25.1	115.4	34	115.5	22.5	117.8	0.881
	Abs Trunk Flexion Strength (N*m)	34	110.1	17.2	112.1	34	107.6	21.1	108.3	0.596
	Abs Trunk Extension Strength (N*m)	34	172.7	45.4	152.7	34	160.0	36.1	161.4	0.207
	Abs Torso Rotation Strength - Stronger Side (N*m)	33	75.0	21.0	72.3	34	77.7	17.2	74.9	0.565
	Abs Torso Rotation Strength - Weaker Side (N*m)	33	69.4	19.5	68.6	34	72.1	17.0	69.8	0.548
	Abs Ankle Eversion Strength - Stronger Side (kg)	35	26.9	5.5	26.1	33	26.5	6.3	24.5	0.808
	Abs Ankle Eversion Strength - Weaker Side (kg)	35	24.2	6.0	23.7	33	24.2	6.3	23.5	0.990
	Abs Ankle Inversion Strength - Stronger Side (kg)	35	23.0	5.6	22.6	34	23.5	5.2	23.1	0.734
	Abs Ankle Inversion Strength - Weaker Side (kg)	35	21.2	5.3	20.2	34	21.3	4.8	20.5	0.925

Strength ratio	Right Shoulder External/Internal Rotation Strength Ratio	34	0.8	0.2	0.8	32	0.8	0.1	0.8	0.729
	Left Shoulder External/Internal Rotation Strength Ratio	34	0.8	0.1	0.8	34	0.8	0.1	0.8	0.788
	Right Knee Flexion/Extension Strength Ratio	34	0.5	0.1	0.6	34	0.5	0.1	0.5	0.461
	Left Knee Flexion/Extension Strength Ratio	34	0.5	0.1	0.5	33	0.6	0.1	0.5	0.643
	Trunk Flexion/Extension Strength Ratio	34	1.6	0.3	1.5	34	1.5	0.3	1.5	0.359
	Right Ankle Eversion/Inversion Strength Ratio	35	1.2	0.2	1.2	32	1.2	0.2	1.1	0.983
	Left Ankle Eversion/Inversion Strength Ratio	34	1.2	0.2	1.2	33	1.1	0.3	1.1	0.423
Flexibility/ Range of motion	Shoulder External Rotation Flexibility - Greater Side (°)	35	109.5	8.0	109.0	34	111.5	9.3	110.7	0.346
	Shoulder External Rotation Flexibility - Lesser Side (°)	35	103.5	7.7	103.7	34	102.8	8.4	102.7	0.713
	Shoulder Internal Rotation Flexibility - Greater Side (°)	35	59.3	7.7	59.0	34	60.7	6.4	59.7	0.401
	Shoulder Internal Rotation Flexibility - Lesser Side (°)	35	53.6	6.3	54.3	34	54.0	5.3	55.0	0.761
	Posterior Shoulder Tightness Flexibility - Greater Side (°)	35	104.1	4.5	103.3	34	106.4	4.8	106.7	0.051
	Posterior Shoulder Tightness Flexibility - Lesser Side (°)	35	97.6	4.1	97.0	34	99.1	4.4	98.8	0.148
	Active Knee Extension (Hamstring) Flexibility - Lesser Side (°)	35	17.0	10.4	16.0	34	19.9	9.5	19.0	0.235
	Active Knee Extension (Hamstring) Flexibility - Greater Side (°)	35	12.6	8.8	13.3	34	14.2	8.0	13.8	0.424
	Ankle Dorsiflexion Flexibility - Greater Side (°)	35	14.5	5.0	15.0	34	13.9	4.5	13.5	0.572
	Ankle Dorsiflexion Flexibility - Lesser Side (°)	35	11.8	4.7	12.3	34	11.7	4.2	10.8	0.923
	Torso Rotation Flexibility - Greater Side (°)	33	78.9	12.8	78.0	34	75.3	11.6	74.2	0.230
	Torso Rotation Flexibility - Lesser Side (°)	33	70.2	12.5	69.0	34	67.2	12.1	66.5	0.323

Balance	Dynamic Postural Stability Index - Worse Side	35	0.4	0.0	0.3	33	0.4	0.0	0.4	0.993
	Dynamic Postural Stability Index - Better Side	35	0.3	0.0	0.3	33	0.3	0.0	0.3	0.551
	Sensory Organization Test (SOT) Score	34	78.7	5.3	78.0	33	78.3	5.9	78.0	0.737
	SOT - Somatosensory Score	35	97.4	3.5	98.0	33	98.4	2.4	99.0	0.167
	SOT - Visual Score	35	84.9	8.1	85.0	33	83.8	11.3	88.0	0.637
	SOT - Vestibular Score	35	69.9	9.5	71.0	33	69.5	10.1	69.0	0.868
	SOT - Preference Score	34	99.1	5.6	98.0	33	100.2	5.2	99.0	0.424
	Single Legged Balance (Eyes Open) - Worse Side (SD vGRF)	35	4.2	1.4	3.9	34	5.0	2.2	4.4	0.082
	Single Legged Balance (Eyes Open) - Better Side (SD vGRF)	35	3.5	0.9	3.4	34	3.9	1.6	3.4	0.152
	Single Legged Balance (Eyes Closed) - Worse Side (SD vGRF)	35	12.7	5.1	11.3	34	12.3	5.0	12.0	0.746
	Single Legged Balance (Eyes Closed) - Better Side (SD vGRF)	35	9.8	3.9	9.1	34	10.4	4.3	10.6	0.529
Lower extremity biomechanics	Hip Flexion at Initial Contact - Better Side (°)	34	36.6	7.8	36.8	33	34.1	6.3	34.3	0.159
	Hip Flexion at Initial Contact - Worse Side (°)	34	32.6	7.7	33.4	33	30.0	6.5	30.6	0.129
	Hip Adduction at Initial Contact - Higher Side (°)	34	-8.3	4.3	-8.3	33	-7.5	4.5	-7.4	0.452
	Hip Adduction at Initial Contact - Lower Side (°)	34	-12.4	3.6	-13.2	33	-12.0	4.1	-11.9	0.653
	Absolute Hip Adduction at Initial Contact - Higher Side (°)	34	12.4	3.6	13.2	33	12.0	4.1	11.9	0.653
	Absolute Hip Adduction at Initial Contact - Lower Side (°)	34	8.5	3.8	8.3	33	7.5	4.5	7.4	0.325
	Knee Flexion at Initial Contact - Better Side (°)	35	16.5	4.5	17.5	33	16.1	5.3	16.1	0.728
	Knee Flexion at Initial Contact - Worse Side (°)	35	12.2	4.3	11.6	33	12.8	5.0	12.2	0.622
	Knee Valgus/Varus at Initial Contact - Higher Side (°)	35	0.4	3.1	0.6	33	-0.2	4.3	-0.2	0.526
	Knee Valgus/Varus at Initial Contact - Lower Side (°)	35	-2.2	3.3	-2.0	33	-2.1	3.7	-2.0	0.886
	Maximal Knee Flexion - Better Side (°)	35	57.3	7.7	58.7	33	55.4	7.5	55.3	0.307
	Maximal Knee Flexion - Worse Side (°)	35	52.8	6.9	52.7	33	51.2	6.8	51.9	0.334
	Peak Vertical Ground Reaction Force - Worse Side (%BW)	35	430.4	60.4	433.1	33	418.9	73.9	389.6	0.482
	Peak Vertical Ground Reaction Force - Better Side (%BW)	35	388.7	51.1	388.5	33	388.0	73.0	378.6	0.959

Physiology	Body Fat (BOD POD) %	35	24.7	4.2	25.7	34	24.0	5.6	22.4	0.570
	Fat Free Mass (kg)	35	49.0	5.3	48.3	34	48.6	5.3	48.9	0.754
	Fat Mass (kg)	35	16.2	3.7	16.1	34	15.5	4.5	15.9	0.523
	Fight Load Index	35	1.1	0.1	1.1	34	1.1	0.2	1.1	0.963
	Abs Peak Anaerobic Power (W)	33	694.5	101.2	692.0	30	667.9	87.5	664.9	0.272
	Abs Mean Anaerobic Capacity (W)	33	374.1	72.7	373.3	30	371.6	82.3	381.6	0.899
	Abs VO2 Max (ml/min)	35	2938.6	346.7	2841.5	32	2815.5	350.3	2820.8	0.154
	Lactate Threshold (%VO2 Max)	34	82.9	5.4	82.5	31	86.3	5.1	86.3	0.010
Field tests	Functional Movement Screen (total score)	35	18.3	1.5	19.0	34	18.0	1.1	18.0	0.413
	Arm Span (cm)	35	65.0	2.6	65.0	34	64.7	2.7	64.6	0.642
	Left Leg Length (cm)	35	866.2	35.2	860.0	34	856.9	37.2	860.0	0.290
	Right Leg Length (cm)	35	867.3	36.0	860.0	34	857.0	38.2	860.0	0.253
	Sit and Reach (cm)	35	32.3	7.5	33.3	34	31.5	8.1	31.2	0.648
	Standing Broad Jump (cm)	35	162.5	20.5	164.3	33	159.9	21.8	159.3	0.604
	Medicine Ball Toss (cm)	35	340.2	42.3	336.7	34	335.6	36.9	337.2	0.633
	Agility Drill - Slower Side (sec)	35	6.0	0.3	6.0	33	6.1	0.3	6.1	0.215
	Agility Drill - Faster Side (sec)	35	5.9	0.3	5.9	33	6.0	0.3	5.9	0.223
	Body Fat (circumference) %	34	28.2	3.5	28.5	33	27.2	4.1	27.0	0.321
PFT and CFT	CFT Movement to Contact (sec)	35	323.4	27.0	322.0	34	325.8	23.4	326.0	0.695
	CFT Maneuver Under Fire (sec)	35	290.7	39.5	300.0	34	283.8	43.7	279.5	0.493
	PFT Crunches (rep)	35	97.4	6.3	100.0	34	97.0	7.4	100.0	0.795
	PFT 3-Mile Run (sec)	35	2325.7	221.3	2326.0	34	2392.0	219.5	2349.0	0.216

Table 25. Results of logistic regression analysis for all subjects (sex, age, ht, wt, Field/PFT/CFT)

	OR (95% CI)	p-value
Sex - male	0.695 (0.304, 1.593)	0.390
Standing Broad Jump (cm)	0.982 (0.967, 0.997)	0.022

Method: sex forced into the model, with stepwise selection on the remaining variables

Table 26. Results of logistic regression analysis for male subjects (sex, age, ht, wt, Field/PFT/CFT)

	OR (95% CI)	p-value
Standing Broad Jump (CM)	0.976 (0.957, 0.996)	0.020

Method: stepwise selection on variables

Table 27. Results of final logistic regression analysis for all subjects combined

	OR (95% CI)	p-value
Sex	1.472 (0.491, 4.417)	0.490
History of injury	0.880 (0.358, 2.167)	0.782
Abs VO2 Max (ml/min)	0.999 (0.998, 1.000)	0.033
Abs Shoulder External Rotation Strength - Weaker Side (N*m)	0.897 (0.825, 0.975)	0.011
Absolute Torso Rotation Strength – Weaker Side (N*m)	1.024 (1.008, 1.041)	0.004

Method: sex and history of injury forced into the model, with stepwise selection on the remaining variables; female is the reference category for sex

Table 28. Results of final logistic regression analysis for male subjects

	OR (95% CI)	p-value
History of injury	0.903 (0.237, 3.441)	0.881
Abs Shoulder External Rotation Strength - Weaker Side (N*m)	0.885 (0.810, 0.968)	0.007
Absolute Torso Rotation Strength – Weaker Side (N*m)	1.027 (1.008, 1.047)	0.005
Abs Ankle Inversion Strength – Weaker Side (N)	0.919 (0.846, 0.998)	0.044
Peak Vertical Ground Reaction Force - Worse Side (%BW)	1.006 (1.001, 1.011)	0.025

Method: history of injury forced into the model, with stepwise selection on the remaining variables

Table 29. Results of final logistic regression analysis for female subjects

	OR (95% CI)	p-value
History of injury	0.652 (0.185, 2.298)	0.506
Lactate Threshold (%VO2 Max)	1.139 (1.027, 1.262)	0.013

Method: history of injury forced into the model, with stepwise selection on the remaining variables

Table 30. Anatomic location of injuries (All Marines)

Injury anatomic location	Time Loss Injuries				All Injuries			
	All injuries		Preventable injuries		All injuries		Preventable injuries	
	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries
Lower extremity	40	75.5	27	81.8	64	64.0	44	67.7
Upper extremity	6	11.3	1	3.0	15	15.0	4	6.2
Spine	4	7.5	4	12.1	18	18.0	16	24.6
Head/face	2	3.8	0	0.0	2	2.0	0	0.0
Unknown	1	1.9	1	3.0	1	1.0	1	1.5
Total	**53**		**33**		**100**		**65**	

Table 31. Anatomic sub-location of injuries (All Marines)

Injury anatomic location	Anatomic sub-location	Time Loss Injuries				All Injuries			
		All injuries		Preventable injuries		All injuries		Preventable injuries	
		Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries
Lower extremity	Hip	8	15.1	8	24.2	12	12.0	11	16.9
	Knee	3	5.7	1	3.0	10	10.0	7	10.8
	Ankle	7	13.2	4	12.1	13	13.0	8	12.3
	Thigh	2	3.8	2	6.1	3	3.0	3	4.6
	Lower leg	1	1.9	0	0.0	4	4.0	3	4.6
	Foot and toes	19	35.8	12	36.4	22	22.0	12	18.5
Upper extremity	Shoulder	3	5.7	1	3.0	7	7.0	3	4.6
	Wrist	0	0.0	0	0.0	2	2.0	1	1.5
	Hand and fingers	3	5.7	0	0.0	5	5.0	0	0.0
	Unknown	0	0.0	0	0.0	1	1.0	0	0.0
Spine	Thoracic	1	1.9	1	3.0	3	3.0	3	4.6
	Lumbopelvic	3	5.7	3	9.1	15	15.0	13	20.0
Head/face	Other	2	3.8	0	0.0	2	2.0	0	0.0
Unknown	Unknown	1	1.9	1	3.0	1	1.0	1	1.5
Total		**53**		**33**		**100**		**65**	

Table 32. Cause of injuries (All Marines)

Cause of injury	Time Loss Injuries				All Injuries			
	All injuries		Preventable injuries		All injuries		Preventable injuries	
	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries
Climbing	1	1.9	1	3.0	2	2.0	1	1.5
Crushing	1	1.9	0	0.0	1	1.0	0	0.0
Direct Trauma	5	9.4	0	0.0	8	8.0	0	0.0
Fall - Different Level	2	3.8	0	0.0	2	2.0	0	0.0
Fall – Same level	1	1.9	0	0.0	1	1.0	0	0.0
Fall – Stairs or Ladder	1	1.9	0	0.0	2	2.0	0	0.0
Fall - Other	2	3.8	0	0.0	2	2.0	0	0.0
Jump	1	1.9	1	3.0	1	1.0	1	1.5
Lifting	0	0.0	0	0.0	3	3.0	3	4.6
Ruck Marching	27	50.9	23	69.7	56	56.0	45	69.2
Running	7	13.2	5	15.2	10	10.0	7	10.8
Twist/Turn/Slip (no fall)	2	3.8	1	3.0	3	3.0	2	3.1
Other	2	3.8	1	3.0	5	5.0	4	6.2
Unknown	1	1.9	1	3.0	4	4.0	2	3.1
Total	**53**		**33**		**100**		**65**	

Table 33. Activity when injury occurred (All Marines)

Activity	Time Loss Injuries				All Injuries			
	All injuries		Preventable injuries		All injuries		Preventable injuries	
	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries
Motor Vehicle Accident	0	0.0	0	0.0	3	3.0	0	0.0
Occupational Tasks	1	1.9	0	0.0	2	2.0	1	1.5
Physical Training	35	66.0	29	87.9	72	72.0	57	87.7
Recreational Activity / Sports	1	1.9	0	0.0	1	1.0	0	0.0
Tactical Training	11	20.8	2	6.1	15	15.0	5	7.7
Other	5	9.4	2	6.1	7	7.0	2	3.1
Total	**53**		**33**		**100**		**65**	

Table 34. Injury type (All Marines)

Injury type	Time Loss Injuries				All Injuries			
	All injuries		Preventable injuries		All injuries		Preventable injuries	
	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries
Bursitis	0	0.0	0	0.0	1	1.0	0	0.0
Chondromalacia/patellofemoral pain	0	0.0	0	0.0	3	3.0	3	4.6
Contusion	1	1.9	0	0.0	1	1.0	0	0.0
Fracture	5	9.4	0	0.0	6	6.0	0	0.0
Inflammation	2	3.8	2	6.1	2	2.0	2	3.1
Laceration / puncture / wound	2	3.8	1	3.0	2	2.0	1	1.5
Pain / spasm / ache	17	32.1	8	24.2	46	46.0	28	43.1
Sprain	7	13.2	4	12.1	13	13.0	8	12.3
Strain	6	11.3	6	18.2	11	11.0	9	13.8
Stress fracture	8	15.1	8	24.2	8	8.0	8	12.3
Tendonitis/ tenosynovitis/ tendinopathy	2	3.8	2	6.1	4	4.0	4	6.2
Other	2	3.8	1	3.0	2	2.0	1	1.5
Unknown	1	1.9	1	3.0	1	1.0	1	1.5
Total	**53**		**33**		**100**		**65**	

Table 35. Onset (All Marines)

	Time Loss Injuries		All Injuries	
	All injuries	**Preventable injuries**	**All injuries**	**Preventable injuries**
Acute	45/53 = 84.9%	28/33 = 84.8%	88/100 = 88.0%	56/65 = 86.2%
Chronic	8/53 = 15.1%	5/33 = 15.2%	12/100 = 12.0%	9/65 = 13.8%

Table 36. Mechanism of injury (All Marines)

	Time Loss Injuries		All Injuries	
	All injuries	**Preventable injuries**	**All injuries**	**Preventable injuries**
Contact	7/53 = 13.2%	0/33 = 0.0%	10/100 = 10.0%	0/65 = 0.0%
Non-contact	44/53 = 83.0%	32/33 = 97.0%	85/100 = 85.0%	63/65 = 96.9%
Unknown	2/53 = 3.8%	1/33 = 3.0%	5/100 = 5.0%	2/65 = 3.1%

Table 37. Anatomic location of injuries (Male Marines)

Injury anatomic location	Time Loss Injuries				All Injuries			
	All injuries		Preventable injuries		All injuries		Preventable injuries	
	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries
Lower extremity	17	65.4	8	66.7	30	60.0	18	62.1
Upper extremity	5	19.2	1	8.3	9	18.0	3	10.3
Spine	3	11.5	3	25.0	10	20.0	8	27.6
Head/face	1	3.8	0	0.0	1	2.0	0	0.0
Total	**26**		**12**		**50**		**29**	

Table 38. Anatomic sub-location of injuries (Male Marines)

Injury anatomic location	Anatomic sub-location	Time Loss Injuries				All Injuries			
		All injuries		Preventable injuries		All injuries		Preventable injuries	
		Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries
Lower extremity	Knee	2	7.7	0	0.0	7	14.0	5	17.2
	Ankle	2	7.7	0	0.0	8	16.0	4	13.8
	Thigh	0	0.0	0	0.0	1	2.0	1	3.4
	Lower leg	1	3.8	0	0.0	1	2.0	0	0.0
	Foot and toes	12	46.2	8	66.7	13	26.0	8	27.6
Upper extremity	Shoulder	3	11.5	1	8.3	6	12.0	3	10.3
	Hand and fingers	2	7.7	0	0.0	3	6.0	0	0.0
Spine	Thoracic	1	3.8	1	8.3	3	6.0	3	10.3
	Lumbopelvic	2	7.7	2	16.7	7	14.0	5	17.2
Head/face	Other	1	3.8	0	0.0	1	2.0	0	0.0
Total		**26**		**12**		**50**		**29**	

Table 39. Cause of injuries (Male Marines)

Cause of injury	Time Loss Injuries				All Injuries			
	All injuries		Preventable injuries		All injuries		Preventable injuries	
	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries
Climbing	1	3.8	1	8.3	1	2.0	1	3.4
Crushing	1	3.8	0	0.0	1	2.0	0	0.0
Direct Trauma	2	7.7	0	0.0	3	6.0	0	0.0
Fall - Different Level	2	7.7	0	0.0	2	4.0	0	0.0
Fall - Same Level	1	3.8	0	0.0	1	2.0	0	0.0
Fall – Stairs or Ladder	1	3.8	0	0.0	2	4.0	0	0.0
Fall - Other	2	7.7	0	0.0	2	4.0	0	0.0
Jump	1	3.8	1	8.3	1	2.0	1	3.4
Lifting	0	0.0	0	0.0	1	2.0	1	3.4
Ruck Marching	10	38.5	7	58.3	24	48.0	18	62.1
Running	0	0.0	0	0.0	3	6.0	2	6.9
Twist/Turn/Slip (no fall)	2	7.7	1	8.3	3	6.0	2	6.9
Other	2	7.7	1	8.3	3	6.0	2	6.9
Unknown	1	3.8	1	8.3	3	6.0	2	6.9
Total	**26**		**12**		**50**		**29**	

Table 40. Activity when injury occurred (Male Marines)

Activity	Time Loss Injuries				All Injuries			
	All injuries		Preventable injuries		All injuries		Preventable injuries	
	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries
Motor Vehicle Accident	0	0.0	0	0.0	1	2.0	0	0.0
Occupational Tasks	1	3.8	0	0.0	2	4.0	1	3.4
Physical Training	12	46.2	8	66.7	33	66.0	24	82.8
Tactical Training	9	34.6	2	16.7	9	18.0	2	6.9
Other	4	15.4	2	16.7	5	10.0	2	6.9
Total	**26**		**12**		**50**		**29**	

Table 41. Injury type (Male Marines)

Injury type	Time Loss Injuries: All injuries – Number of injuries	Time Loss Injuries: All injuries – Percent of injuries	Time Loss Injuries: Preventable injuries – Number of injuries	Time Loss Injuries: Preventable injuries – Percent of injuries	All Injuries: All injuries – Number of injuries	All Injuries: All injuries – Percent of injuries	All Injuries: Preventable injuries – Number of injuries	All Injuries: Preventable injuries – Percent of injuries
Bursitis	0	0.0	0	0.0	1	2.0	0	0.0
Chondromalacia/patellofemoral pain	0	0.0	0	0.0	3	6.0	3	10.3
Contusion	1	3.8	0	0.0	1	2.0	0	0.0
Fracture	5	19.2	0	0.0	5	10.0	0	0.0
Inflammation	2	7.7	2	16.7	2	4.0	2	6.9
Pain / spasm / ache	7	26.9	2	16.7	18	36.0	10	34.5
Sprain	2	7.7	0	0.0	8	16.0	4	13.8
Strain	2	7.7	2	16.7	5	10.0	4	13.8
Stress fracture	6	23.1	6	50.0	6	12.0	6	20.7
Other	1	3.8	0	0.0	1	2.0	0	0.0
Total	**26**		**12**		**50**		**29**	

Table 42. Onset (Male Marines)

	Time Loss Injuries		All Injuries	
	All injuries	**Preventable injuries**	**All injuries**	**Preventable injuries**
Acute	22/26 = 84.6%	10/12 = 83.3%	45/50 = 90.0%	26/29 = 89.7%
Chronic	4/26 = 15.4%	2/12 = 16.7%	5/50 = 10.0%	3/29 = 10.3%

Table 43. Mechanism of injury (Male Marines)

	Time Loss Injuries		All Injuries	
	All injuries	**Preventable injuries**	**All injuries**	**Preventable injuries**
Contact	4/26 = 15.4%	0/12 = 0.0%	5/50 = 10.0%	0/29 = 0.0%
Non-contact	20/26 = 76.9%	11/12 = 91.7%	42/50 = 84.0%	28/29 = 96.6%
Unknown	2/26 = 7.7%	1/12 = 8.3%	3/50 = 6.0%	1/29 = 3.4%

Table 44. Anatomic location of injuries (Female Marines)

Injury anatomic location	Time Loss Injuries				All Injuries			
	All injuries		Preventable injuries		All injuries		Preventable injuries	
	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries
Lower extremity	23	85.2	19	90.5	34	68.0	26	72.2
Upper extremity	1	3.7	0	0.0	6	12.0	1	2.8
Spine	1	3.7	1	4.8	8	16.0	8	22.2
Head/Face	1	3.7	0	0.0	1	2.0	0	0.0
Unknown	1	3.7	1	4.8	1	2.0	1	2.8
Total	**27**		**21**		**50**		**36**	

Table 45. Anatomic sub-location of injuries (Female Marines)

Injury anatomic location	Anatomic sub-location	Time Loss Injuries				All Injuries			
		All injuries		Preventable injuries		All injuries		Preventable injuries	
		Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries
Lower extremity	Hip	8	29.6	8	38.1	12	24.0	11	30.6
	Knee	1	3.7	1	4.8	3	6.0	2	5.6
	Ankle	5	18.5	4	19.0	5	10.0	4	11.1
	Thigh	2	7.4	2	9.5	2	4.0	2	5.6
	Lower leg	0	0.0	0	0.0	3	6.0	3	8.3
	Foot and toes	7	25.9	4	19.0	9	18.0	4	11.1
Upper extremity	Shoulder	0	0.0	0	0.0	1	2.0	0	0.0
	Wrist	0	0.0	0	0.0	2	4.0	1	2.8
	Hand and fingers	1	3.7	0	0.0	2	4.0	0	0.0
	Unknown	0	0.0	0	0.0	1	2.0	0	0.0
Spine	Lumbopelvic	1	3.7	1	4.8	8	16.0	8	22.2
Head/Face	Other	1	3.7	0	0.0	1	2.0	0	0.0
Unknown	Unknown	1	3.7	1	4.8	1	2.0	1	2.8
Total		**27**		**21**		**50**		**36**	

Table 46. Cause of injuries (Female Marines)

Cause of injury	Time Loss Injuries				All Injuries			
	All injuries		Preventable injuries		All injuries		Preventable injuries	
	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries
Climbing	0	0.0	0	0.0	1	2.0	0	0.0
Direct Trauma	3	11.1	0	0.0	5	10.0	0	0.0
Lifting	0	0.0	0	0.0	2	4.0	2	5.6
Ruck Marching	17	63.0	16	76.2	32	64.0	27	75.0
Running	7	25.9	5	23.8	7	14.0	5	13.9
Other	0	0.0	0	0.0	2	4.0	2	5.6
Unknown	0	0.0	0	0.0	1	2.0	0	0.0
Total	**27**		**21**		**50**		**36**	

Table 47. Activity when injury occurred (Female Marines)

Activity	Time Loss Injuries				All Injuries			
	All injuries		Preventable injuries		All injuries		Preventable injuries	
	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries	Number of injuries	Percent of injuries
Motor Vehicle Accident	0	0.0	0	0.0	2	4.0	0	0.0
Occupational Tasks	0	0.0	0	0.0	0	0.0	0	0.0
Physical Training	23	85.2	21	100.0	39	78.0	33	91.7
Recreational Activity / Sports	1	3.7	0	0.0	1	2.0	0	0.0
Tactical Training	2	7.4	0	0.0	6	12.0	3	8.3
Other	1	3.7	0	0.0	2	4.0	0	0.0
Total	**27**		**21**		**50**		**36**	

Table 48. Injury type (Female Marines)

	Time Loss Injuries				All Injuries			
Injury type	**All injuries**		**Preventable injuries**		**All injuries**		**Preventable injuries**	
	Number of injuries	**Percent of injuries**	**Number of injuries**	**Percent of injuries**	**Number of injuries**	**Percent of injuries**	**Number of injuries**	**Percent of injuries**
Fracture	0	0.0	0	0.0	1	2.0	0	0.0
Laceration/ puncture/ wound	2	7.4	1	4.8	2	4.0	1	2.8
Pain/spasm/ache	10	37.0	6	28.6	28	56.0	18	50.0
Sprain	5	18.5	4	19.0	5	10.0	4	11.1
Strain	4	14.8	4	19.0	6	12.0	5	13.9
Stress fracture	2	7.4	2	9.5	2	4.0	2	5.6
Tendonitis/ tenosynovitis/ tendinopathy	2	7.4	2	9.5	4	8.0	4	11.1
Other	1	3.7	1	4.8	1	2.0	1	2.8
Unknown	1	3.7	1	4.8	1	2.0	1	2.8
Total	**27**		**21**		**50**		**36**	

Table 49. Onset (Female Marines)

	Time Loss Injuries		All Injuries	
	All injuries	**Preventable injuries**	**All injuries**	**Preventable injuries**
Acute	23/27 = 85.2%	18/21 = 85.7%	43/50 = 86.0%	30/36 = 83.3%
Chronic	4/27 = 14.8%	3/21 = 14.3%	7/50 = 14.0%	6/36 = 16.7%

Table 50. Mechanism of injury (Female Marines)

	Time Loss Injuries		All Injuries	
	All injuries	**Preventable injuries**	**All injuries**	**Preventable injuries**
Contact	3/27 = 11.1%	0/21 = 0.0%	5/50 = 10.0%	0/36 = 0.0%
Non-contact	24/27 = 88.9%	21/21 = 100.0%	43/50 = 86.0%	35/36 = 97.2%
Unknown	0/27 = 0.0%	0/21 = 0.0%	2/50 = 4.0%	1/36 = 2.8%

Table 51. UPitt Variables Associated with Infantry Tasks

0311, 0331, 0341, 035X, PI, PIMG	Male Marines				Female Marines			
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Anaerobic Power (W)	1000.12	179.27	605.43	1499.93	684.48	111.81	460.17	965.43
Anaerobic Capacity (W)	599.33	112.79	322.80	893.54	366.66	87.81	171.87	552.85
Aerobic Capacity (ml/min)	3944.69	535.13	2944.30	5491.00	2862.99	400.21	2000.20	3946.00
Fat Free Mass (kg)	65.27	7.81	47.86	84.42	49.53	5.86	38.95	63.72
Fight Load Parameter	0.80	0.12	0.55	1.24	1.08	0.14	0.74	1.41
Arm Span (cm)	71.27	3.07	64.00	79.00	65.10	3.25	58.00	73.5.00
Right Leg Length (cm)	934.86	46.83	805.00	1060.00	863.81	43.98	780.00	965.00
***Knee Flexion Strength (N*m)**	100.12	22.47	48.10	177.10	68.67	14.96	34.6	103.10
***Knee Extension Strength (N*m)**	188.58	43.75	86.40	326.80	127.40	25.39	71.7	176.00
Trunk Flexion Strength (N*m)	161.89	38.06	78.80	271.10	109.64	23.44	69.4	177.80
Trunk Extension Strength (N*m)	262.07	73.24	102.90	521.90	166.11	34.50	94.00	247.90
***Shoulder Internal Rot Strength (N*m)**	47.94	13.90	23.60	94.20	25.98	6.48	15.20	47.70
***Shoulder External Rot Strength (N*m)**	34.42	7.22	19.50	56.60	20.69	3.72	14.20	32.20
***Ankle Inversion Strength (kg)**	25.75	6.14	13.90	50.20	23.26	4.79	13.30	34.90
***Ankle Eversion Strength (kg)**	29.72	6.11	17.10	55.50	26.46	5.40	16.90	37.10
Medicine Ball Toss (cm)	498.78	70.60	344.67	698.00	345.74	50.36	242.00	532.33
Standing Broad Jump (cm)	200.78	23.58	153.00	290.33	165.77	21.11	115.00	215.00
Functional Movement Screen (score)	17.44	1.76	9.00	21.00	18.00	1.47	12.00	20.00
****Dynamic Postural Stability Index**	0.35	0.03	0.47	0.27	0.34	0.03	0.40	0.25
†Shoulder Internal Rot Flexibility (°)	58.159	5.4977	40.70	70.70	61.16	5.87	49.70	71.30
†Shoulder External Rot Flexibility (°)	106.84	8.98	84.30	126.30	111.68	8.75	93.70	139.30

*All strength measures reported for the stronger side only
**DPSI reported for better side only (lower score is better)
†Flexibility reported for the greater side only

Table 52. UPitt Variables Associated with Artillery Tasks

0811	Male Marines				Female Marines			
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Anaerobic Power (W)	1063.82	149.15	788.80	1328.55	693.60	87.53	551.54	867.11
Anaerobic Capacity (W)	585.76	107.98	452.55	821.98	381.62	66.22	260.79	478.41
Aerobic Capacity (ml/min)	3956.67	567.26	3207.10	5079.30	2840.39	328.86	2385.60	3489.50
Fat Free Mass (kg)	66.64	6.43	53.97	75.58	47.89	5.11	36.57	54.78
Arm Span (cm)	72.04	2.78	67.25	77.00	65.14	2.51	60.50	69.00
Right Leg Length (cm)	951.67	44.91	840.00	1005.00	866.92	26.50	825.00	905.00
***Knee Flexion Strength (N*m)**	95.19	26.54	39.10	139.90	69.44	13.80	44.50	93.60
***Knee Extension Strength (N*m)**	188.58	43.75	86.40	326.80	129.21	23.51	92.60	160.80
***Torso Rotation Strength (N*m)**	120.58	21.28	78.60	149.90	71.02	18.95	47.70	110.40
Trunk Flexion Strength (N*m)	161.89	38.06	78.80	271.10	112.15	16.77	84.80	142.30
Trunk Extension Strength (N*m)	261.58	69.78	153.50	388.30	171.91	47.30	123.60	274.50
***Shoulder Internal Rot Strength (N*m)**	48.58	10.97	27.70	69.70	24.39	5.03	19.00	33.40
***Shoulder External Rot Strength (N*m)**	33.19	5.67	20.30	41.70	19.38	3.50	13.40	25.60
***Ankle Inversion Strength (kg)**	27.28	6.72	20.00	42.10	19.70	3.67	13.70	24.40
***Ankle Eversion Strength (kg)**	32.19	7.43	23.00	45.70	23.02	3.00	18.30	26.70
Medicine Ball Toss (cm)	480.13	56.29	413.33	562.67	332.97	28.26	300.00	399.33
Standing Broad Jump (cm)	199.78	25.81	157.33	237.33	162.49	17.77	138.00	205.00
Functional Movement Screen (score)	17.24	1.52	14.00	20.00	17.36	1.34	15.00	19.00
‡Agility Drill Time (sec)	5.39	0.23	5.74	4.92	5.93	0.18	6.23	5.67
****Dynamic Postural Stability Index**	0.35	0.04	0.29	0.43	0.34	0.04	0.26	0.41
†Shoulder Internal Rot Flexibility (°)	56.41	4.48	50.00	63.00	56.49	8.89	42.00	75.30
†Shoulder External Rot Flexibility (°)	106.65	8.14	92.00	125.70	108.55	8.11	99.30	120.30
†Ankle Dorsiflexion Flexibility (°)	12.87	5.49	5.70	23.70	13.60	5.36	4.70	24.00
†Torso Rotation Flexibility (°)	70.49	9.36	58.30	87.70	74.82	12.28	58.00	98.70

*All strength measures reported for the stronger side only

**DPSI reported for better side only (lower score is better)

‡Lower (faster) time is better for the Agility Drill

†Flexibility reported for the greater side only

Table 53. UPitt Variables Associated with Combat Engineer Tasks

1371	Male Marines				Female Marines			
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Anaerobic Power (W)	979.00	178.48	678.97	1291.41	636.02	91.47	554.48	782.83
Anaerobic Capacity (W)	552.92	130.38	310.39	805.32	363.30	48.85	269.79	423.52
Aerobic Capacity (ml/min)	3889.14	587.55	2908.90	4586.20	2657.23	225.68	2286.10	2895.10
Fat Free Mass (kg)	63.71	9.39	49.21	77.50	45.46	4.73	39.41	52.72
Fight Load Parameter	0.87	0.17	0.59	1.22	1.16	0.10	1.06	1.30
Arm Span (cm)	70.96	3.45	64.00	76.50	64.03	1.56	62.00	66.00
Right Leg Length (cm)	945.00	53.82	845.00	1030.00	855.00	36.25	810.00	905.00
***Knee Flexion Strength (N*m)**	96.121	19.34	54.60	130.30	63.14	12.55	45.90	86.00
***Knee Extension Strength (N*m)**	174.99	39.78	96.70	254.90	114.96	21.27	85.10	147.80
***Torso Rotation Strength (N*m)**	105.27	26.58	58.70	158.10	71.44	14.25	53.00	87.40
Trunk Flexion Strength (N*m)	147.16	34.62	90.80	225.90	100.95	16.02	87.10	130.30
Trunk Extension Strength (N*m)	234.52	46.59	154.80	316.50	152.36	31.70	124.20	217.20
***Shoulder Internal Rot Strength (N*m)**	44.78	10.03	28.60	61.10	23.29	6.52	10.80	30.90
***Shoulder External Rot Strength (N*m)**	32.87	5.47	22.70	42.60	18.88	2.91	15.50	23.00
***Ankle Inversion Strength (kg)**	24.60	9.15	12.60	42.00	21.89	4.79	13.30	34.90
***Ankle Eversion Strength (kg)**	28.61	5.66	18.80	38.00	25.14	7.73	14.50	36.90
Medicine Ball Toss (cm)	480.93	64.91	363.33	562.00	320.96	42.83	270.00	386.67
Standing Broad Jump (cm)	192.52	25.25	142.67	239.00	146.29	19.08	122.00	166.00
Functional Movement Screen (score)	16.64	2.02	2.02	2.02	18.88	0.99	17.00	20.00
‡Agility Drill Time (sec)	5.41	0.25	4.94	5.83	6.021	0.20	5.81	6.34
****Dynamic Postural Stability Index**	0.35	0.02	0.39	0.31	0.32	0.03	0.36	0.29
†Torso Rot Flexibility (°)	76.07	12.70	56.30	97.00	80.80	15.51	60.00	105.70
†Shoulder External Rot Flexibility (°)	108.36	8.33	91.30	121.30	108.33	7.37	94.30	118.00

*All strength measures reported for the stronger side only
**DPSI reported for better side only (lower score is better)
‡Lower (faster) time is better for the Agility Drill
†Flexibility reported for the greater side only

Table 54. UPitt Variables Associated with Vehicle Tasks

0313, 1812, 1833	Male Marines				Female Marines			
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Anaerobic Power (W)	985.92	171.57	598.19	1372.09	674.0644	69.00	595.44	820.33
Anaerobic Capacity (W)	591.45	121.62	244.42	799.10	361.34	57.76	57.76	57.76
Aerobic Capacity (ml/min)	3941.62	440.14	2987.10	5214.40	2902.79	226.07	2502.80	3143.50
Fat Free Mass (kg)	64.93	7.06	53.96	87.35	47.86	3.57	43.02	52.36
Arm Span (cm)	71.69	3.03	65.50	80.00	64.69	2.60	60.00	69.00
Right Leg Length (cm)	935.73	45.51	830.00	1020.00	857.77	37.66	795.00	926.00
***Knee Flexion Strength (N*m)**	95.46	22.05	48.70	139.20	67.99	9.61	56.10	87.90
***Knee Extension Strength (N*m)**	177.89	39.33	82.70	279.00	125.33	17.70	95.60	161.20
***Torso Rotation Strength (N*m)**	113.35	31.54	59.00	186.40	68.44	13.86	36.90	96.50
Trunk Flexion Strength (N*m)	156.51	35.21	78.50	273.50	110.88	15.67	89.80	137.90
Trunk Extension Strength (N*m)	246.67	62.33	127.20	384.90	166.78	53.09	94.20	275.50
***Shoulder Internal Rot Strength (N*m)**	44.38	12.45	24.30	81.40	24.72	3.85	17.30	30.10
***Shoulder External Rot Strength (N*m)**	33.26	6.41	20.80	48.90	19.01	2.25	15.50	22.20
***Ankle Inversion Strength (kg)**	27.52	5.80	19.30	41.80	26.64	5.13	19.00	35.70
***Ankle Eversion Strength (kg)**	31.51	7.70	16.80	54.90	29.72	5.58	21.70	38.90
Medicine Ball Toss (cm)	496.02	68.16	360.00	643.67	347.97	35.15	304.33	415.33
Standing Broad Jump (cm)	202.02	22.72	156.00	249.67	155.78	20.05	124.00	186.33
Functional Movement Screen (score)	17.42	1.61	14.00	20.00	18.08	1.61	15.00	20.00
‡Agility Drill Time (sec)	5.38	0.27	5.95	4.89	5.81	0.33	6.33	5.26
****Dynamic Postural Stability Index**	0.35	0.04	0.27	0.52	0.34	0.02	0.38	0.31
Knee Flexion at Initial Contact (°)	10.66	4.59	4.74	20.74	12.86	5.15	4.56	22.51
****Peak Ground Reaction Force (%BW)**	403.97	69.84	577.28	276.86	393.27	40.01	467.18	330.41
*****Sensory Organization Test (score)**	79.15	4.53	64.00	85.00	78.38	3.97	74.00	86.00
†Shoulder Internal Rot Flexibility (°)	58.44	6.15	45.70	68.30	58.79	7.56	46.70	70.30
†Shoulder External Rot Flexibility (°)	110.02	10.18	86.70	126.00	108.23	8.16	93.30	120.30
†Posterior Shoulder Flexibility (°)	101.61	4.73	93.30	113.70	105.17	4.96	98.00	118.30
†*Active Knee Extension Flexibility (°)	22.96	9.08	45.30	3.30	14.38	10.94	41.70	0.30
†Torso Rotation Flexibility (°)	81.57	13.25	50.00	113.30	77.13	14.31	56.30	104.00

*All strength measures reported for the stronger side only
‡Lower (faster) time is better for the Agility Drill
**DPSI and peak Vertical Ground Reaction Force reported for better side only (lower score is better)
***Higher score is better (out of 100 points)
†Flexibility reported for the greater side only
†*Lower degree of knee angle indicates better hamstring flexibility

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