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**14. ABSTRACT**
This collaborative research proposal was submitted to program announcement W81XWH-09-DMRDP-ARATDA at the request of the command surgeon of the United States Army Special Operations Command (USASOC) to scientifically develop THOR3's injury prevention and human performance program. This research will conduct the first three phrases of a four phase research objective to ultimately improve physical readiness and mitigate unintentional musculoskeletal injuries.

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## Introduction

Unintentional musculoskeletal injuries limit tactical readiness, shorten the active duty life cycle, and diminish the quality of life of the personnel after military service. Many of these injuries are preventable or their severity mitigated through implementation of demand-specific physical training for injury prevention and performance optimization developed through scientific research. At the request of the Command Surgeon from the United States Army Special Operations Command (USASOC), this research will support development of USASOC's Tactical Human Optimization, Rapid Rehabilitation, and Reconditioning (THOR3) program to identify the priorities necessary for enhancement and change in the current physical training program. Consistent with our injury prevention and performance optimization model previously developed from over 20 years of research with elite athletes and six years of collective research with Naval Special Warfare Group 2 (NSWG2) and the 101st Airborne (Air Assault), this will address the cause and prevention of musculoskeletal injury and detriments to optimal performance by identifying suboptimal biomechanical, musculoskeletal, physiological, and nutritional characteristics that are task and demand-specific to the Special Forces soldier.

## Body

### Project Overview

This collaborative research was modeled after our research with Naval Special Warfare and was submitted to program announcement W81XWH-09-DMRDP-ARATDA at the request of the Command Surgeon of the United States Army Special Operations Command (USASOC) to support development of USASOC's Tactical Human Optimization, Rapid Rehabilitation, and Reconditioning (THOR3) program and identify the priorities necessary for improvement and growth in their current physical training program. The overall objective of our four phase research initiative is to provide the scientific arm by which USASOC will refine its THOR3 program. It is our intent the research will result in a validated THOR3 program that reduces unintentional musculoskeletal injury and improves physical and tactical readiness. The current research under this award will test the first three phases of research and is hypothesized to result in identified injury characteristics and risk factors of the USASOC Operator and a validated THOR3 program which alters injury risk characteristics. This research addresses the project/tasks as outlined in Funding Opportunity Number: W81XWH-09-DMRDP-ARATDA (Operational Health and Performance-Fundamental Mechanisms of Training and Operational Injury). The fourth and final phase of research will test the THOR3 program to reduce unintentional musculoskeletal injury (not part of the current research-to be submitted under a separate SOW).

This research includes activities performed at the USASOC/University of Pittsburgh Human Performance Research Laboratory at Fort Bragg, NC and protocol development, research monitoring, verification of data integrity, report preparation, and data processing/interpretation completed at the Neuromuscular Research Laboratory, University of Pittsburgh, Pittsburgh, PA.

### Statement of Work:

**Phase 1 Aim 1: To perform an epidemiological analysis of the unintentional musculoskeletal injuries sustained by USASOC Operators**

**Methods:** A descriptive epidemiological design will be used to analyze retrospective unintentional musculoskeletal injury data from the previous five years of operation. Injury data will be queried from the Armed Forces Health Surveillance Center (AFHSC) and medical records maintained by the medical and physical therapy personnel of USASOC. Injury data from the AFHSC will be queried based on ICD-9 codes 710-739 and 800-899 and when available supplemented with ICD-9 E codes (external causes of injury codes). Individual encounters will be reported based on the ICD-9/ICD-9 E codes for a given anatomic region, limb, and identified with the corresponding time category for date range. Encounters will be defined as one injury per anatomic region every 60 days. Demographic data including age, height, and weight will be reported. Injury data queried by the medical and physical therapy personnel of USASOC will provide a summary of injury mechanisms to supplement the ICD-9 E codes. Phase 1 Aim 1 research activities will be performed in Y1Q1-Y1Q2.

**Deliverables:** The data from this aim will measure the frequency of unintentional musculoskeletal injury sustained by the USASOC Operator. The data from this aim will also be used to modify laboratory testing in Phase 2 should group-specific injury patterns be identified. This specific aim will also be used to identify the necessary procedures for injury data collection in Phase 4. The data from this aim will be submitted for publication with authors from the University of Pittsburgh and Command Surgeon of the US Army Special Operations Command. The authors submit the paper with the understanding that the manuscript has been read and approved by all authors and that all authors agree to the submission of the manuscript to the peer-reviewed journal. All named authors must have made an active contribution to the conception and design and/or analysis and interpretation of the data and/or the drafting of the paper and all must have critically reviewed its content and have approved the final version submitted for publication.

**Phase 1 Aim 2: To describe the tactical and physical tasks which result in the greatest proportion of unintentional musculoskeletal injuries**

**Methods:** Based on the injury data and in consultation with USASOC personnel (training, medical, human performance, and Team Sergeants) representative tactical tasks will be identified to quantify segmental accelerations of the spine and lower extremity and describe the biomechanical and musculoskeletal demands. Collaboration with USASOC personnel will identify the mission-specific tasks which result in unintentional musculoskeletal injury. Data will be examined on a sample of Operators based on the identified tactical tasks. Injury data from the medical and physical therapy personnel of USASOC will support identification of appropriate tasks which result in significant injury to the USASOC Operator.

**Deliverables:** The data from this aim will be used to supplement the injury data identified in Phase 1 Aim 1 to further describe the injuries sustained by the USASOC Operators. The data from this aim will also be used to develop functional laboratory tests to replicate USASOC-specific demands. This specific aim will also be used to identify the necessary procedures for injury data collection in Phase 4. The data from this aim will be submitted for publication with authors from the University of Pittsburgh and Command Surgeon of the US Army Special Operations Command. The authors submit the paper with the understanding that the manuscript has been read and approved by all authors and that all authors agree to the submission of the manuscript to the peer-reviewed journal. All named authors must have made an active contribution to the conception and design and/or analysis and interpretation of the data and/or the drafting of the paper and all must have critically reviewed its content and have approved the final version submitted for publication.

**Phase 2 Aim 1: To prospectively identify biomechanical, musculoskeletal, physiological, and nutritional risk factors for injury in USASOC Operators**

**Methods:** A prospective analysis of risk factors for unintentional musculoskeletal injury will be conducted based on biomechanical, musculoskeletal, and physiological data collection. The biomechanical characteristics of the knee, shoulder, and torso will be analyzed using a 3D motion analysis and force plate system. Isokinetic and isometric strength of the neck, torso, shoulder, knee, hip, and ankle will be measured with an isokinetic device or handheld dynamometer. Range of motion of the neck, torso, shoulder, knee, hip, and ankle will be assessed with goniometers. Static and dynamic balance will be assessed with force plates and a stability system. Body composition will be measured with air displacement plethysmography. Aerobic capacity and lactate threshold will be measured with a metabolic system and lactate analyzer. Anaerobic power and capacity will be measured with an electromagnetic ergometer. Nutrition data will include a 24 hour recall and nutrition history. The 24 hour recall will be assessed with the ASA 24 to assess food types and quantities. A nutrition history will assess supplement intake, overall habits, and fueling and hydration habits before, during, and after physical training. These data will be analyzed in relation to prospectively collected unintentional musculoskeletal injury data (self-reported, AFHSC, medical and physical therapist-reported). Injury data will be captured for the 12 month period following laboratory testing. It is our intent that utilizing several sources of injury data will improve the validity of the data query for completeness without relying solely on an individual source where potential injuries, mechanisms, or tasks may be empty. Based on a cumulative incidence of 13-22% injured for given musculoskeletal injuries up to 480 subjects will be required to identify biomechanical, musculoskeletal, and physiological contributors to injury with a power of 0.80 and statistical power of $p < 0.05$. Phase 2 Aim 1 research activities will be performed Y1Q3-Y3Q4.

**Deliverables:** The data from this phase will prospectively identify risk factors for unintentional musculoskeletal injury. The data may be used as a screening mechanism to identify individual Operators who may be at a greater risk of injury due to established risk factors. This data will be provided to USASOC's THOR3 human performance personnel to integrate into current physical training for validation in Phase 3. Specific recommendations will be made for changes in the THOR3 program based upon the data obtained. The data from this aim are the foundation by which the THOR3 program will be implemented in Phase 4. The data from this aim will be submitted for publication with authors from the University of Pittsburgh and Command Surgeon of the US Army Special Operations Command. The authors submit the paper with the understanding that the manuscript has been read and approved by all authors and that all authors agree to the submission of the manuscript to the peer-reviewed journal. All named authors must have made an active contribution to the conception and design and/or analysis and interpretation of the data and/or the drafting of the paper and all must have critically reviewed its content and have approved the final version submitted for publication.

**Phase 2 Aim 2: To determine the relationship between previous history of unintentional musculoskeletal injury and biomechanical, musculoskeletal, physiological, and tactical characteristics**

**Methods:** Biomechanical, musculoskeletal, physiological data captured during Phase 2 Aim 1 and tactical characteristics will be evaluated to determine the relationship with retrospective unintentional musculoskeletal injury history. Unintentional musculoskeletal injury data will be captured with a self-reported questionnaire to identify the frequency of injury, mechanisms, tasks, and other contributing factors of the injury event. Phase 2 Aim 2 research activities will be performed Y1Q3-Y3Q4.

**Deliverables:** The data from this aim will identify potential residual deficits as a function of previous injury and impact as confounding factors to laboratory testing. The data from this aim are the foundation by which the THOR3 program will be implemented in Phase 4. The data from this aim will be submitted for publication with authors from the University of Pittsburgh and Command Surgeon of the US Army Special Operations Command. The authors submit the paper with the understanding that the manuscript has been read and approved by all authors and that all authors agree to the submission of the manuscript to the peer-reviewed journal. All named authors must have made an active contribution to the conception and design and/or analysis and interpretation of the data and/or the drafting of the paper and all must have critically reviewed its content and have approved the final version submitted for publication.

**Phase 2 Aim 3: To identify suboptimal biomechanical, musculoskeletal, physiological, tactical, and nutritional characteristics for physical readiness in the USASOC Operator**

**Methods:** Biomechanical, musculoskeletal, physiological, and tactical readiness data captured in Phase 2 Aim 2 will be analyzed for suboptimal contributors to physical readiness. Biomechanical, musculoskeletal, physiological, and nutrition data will be compared to data sets of athletes, evidenced-based practice, and tactical athletes when appropriate. These data sets will include athletes tested at the Neuromuscular Research Laboratory at the University of Pittsburgh, literature demonstrating risk factors for unintentional musculoskeletal injury, characteristics of suboptimal performance, and data from tactical athletes from other University of Pittsburgh US Special Operations Command research projects. This comprehensive approach will be utilized to identify specific suboptimal characteristics relative to performance optimization without relying solely on an individual source for comparison. An additional USASOC tactical athlete cohort from the current study will be included once sufficient data are obtained to primarily test the tactical readiness characteristics. Phase 2 Aim 3 research activities will be performed Y1Q3-Y3Q1.

**Deliverables:** The data from this aim will establish suboptimal physical readiness characteristics based on comparison to athlete, evidence-based, and tactical athlete optimization data sets. The data will be provided to USASOC's THOR3 human performance personnel to integrate into current physical training for testing in Phase 3 and Phase 4 (not part of the current submission- to be submitted under a separate SOW). The nutrition data will be provided to the THOR3 registered dietitian for immediate implementation into clinical practice and not further tested with Phase 3 or 4. The data from this aim will be submitted for publication with authors from the University of Pittsburgh and Command Surgeon of the US Army Special Operations Command. The authors submit the paper with the understanding that the manuscript has been read and approved by all authors and that all authors agree to the submission of the manuscript to the peer-reviewed journal. All named authors must have made an active contribution to the conception and design and/or analysis and interpretation of the data and/or the drafting of the paper and all must have critically reviewed its content and have approved the final version submitted for publication.

**Phase 3: To validate THOR3's human performance program to modify injury mitigating and human performance characteristics identified in Phase 2**

**Methods:** Upon receipt of the Phase 1 and Phase 2 results, USASOC's THOR3 human performance personnel will evaluate the biomechanical, musculoskeletal, physiological, tactical, and injury data and refine its current human performance program to address the injury mitigating and human performance characteristics. A randomized controlled clinical trial intervention design will be implemented with USASOC Operator units assigned to either an experimental (revised THOR3 training) or control (current THOR3 training) group as part of the intervention. Pre- and post-testing of biomechanical, musculoskeletal, physiological, and tactical characteristics will be performed as outlined in Phase 2. THOR3's revised human performance program will be tested in a 12 week intervention and instructed by THOR3 human performance personnel as part of their daily training of the Operators. Based on several individual power analyses performed for the dependent variables (biomechanical, musculoskeletal, physiological) to be assessed during this aim, quadriceps strength data yielded the most conservative estimate and was selected to calculate the sample size. Previously collected data (Quadriceps Strength Mean: $271.7 \pm 59.3$) and an expected effect size improvement of 0.69 following the intervention indicated a total of 150 subjects will be needed to achieve a power of 0.80 with a probability of $p < 0.05$. A total of 200 subjects will be recruited to account for attrition. Phase 3 research activities will be performed Y3Q2-Y3Q4.

**Deliverables:** The data from this aim will test the effectiveness of the revised THOR3 program to modify the identified biomechanical, musculoskeletal, physiological, and tactical characteristics that predict injury, physical readiness, and tactical performance. Based upon the results of this aim, the THOR3 program may be augmented to address insufficient findings prior to formal implementation into USASOC Operator training and testing for injury mitigation in Phase 4. The data from this aim will be submitted for publication with authors from the University of Pittsburgh and Command Surgeon of the US Army Special Operations Command. The authors submit the paper with the understanding that the manuscript has been read and approved by all authors and that all authors agree to the submission of the manuscript to the peer-reviewed journal. All named authors must have made an active contribution to the conception and design and/or analysis and interpretation of the data and/or the drafting of the paper and all must have critically reviewed its content and have approved the final version submitted for publication.

**Overall Deliverables and Way Forward:** Phase 4 of the research (not part of the current submission- to be submitted under a separate SOW) will test the effectiveness of the THOR3 program to mitigate unintentional musculoskeletal injuries with a larger prospective study. Injury data will be evaluated pre- and post-implementation of the revised THOR3 program and between like tactical units. This phase of research will incorporate subjects from across USASOC and evaluate stratified data based on tactical requirements.

## Key Research Accomplishments

**Phase 1 Aim 1: To perform an epidemiological analysis of the unintentional musculoskeletal injuries sustained by USASOC Operators**

Self-reported musculoskeletal injury data were collected on 106 personnel (Age: $31.7 \pm 5.3$ years, Height: $179.0 \pm 5.5$ cm, Mass: $85.9 \pm 10.9$ kg) from 3rd Special Forces Group (3SFG) for one year prior to the date of laboratory testing. Injury data were captured with the University of Pittsburgh Military Epidemiological Database (UPitt-MED) while assisted by a clinically-trained research associate to ensure an accurate and thorough injury history. The frequency of musculoskeletal injuries was 24.5 injuries/100 subjects/year for total injuries and 18.9 injuries/100 subjects/year for preventable injuries. The incidence of musculoskeletal injuries was 20.8 injured subjects/100 subjects/year for total injuries and 16.0 injured subjects/100 subjects/year for preventable injuries. Preventable musculoskeletal injuries comprised 76.9% of total injuries. The knee and shoulder were the most common reported locations for total injuries (each 23.1%) and preventable injuries (each 25.0%). Preventable musculoskeletal injuries were classified as 60% acute, 35% chronic/overuse, and 5.0% other/unknown. Physical training (PT) was the most reported activity for total injuries (PT Command Organized: 46.2%, PT Non Command Organized: 7.7%, PT Unknown: 3.8%) and preventable injuries (PT Command Organized: 60.0%, PT Non Command Organized: 10.0%, PT Unknown: 5.0%). ***A complete Phase 1 Aim 1 summary of data is provided in Appendix 1 and 2.***

**Phase 1 Aim 2: To describe the tactical and physical tasks which result in the greatest proportion of unintentional musculoskeletal injuries**
Data collection ongoing.

**Phase 2 Aim 1: To prospectively identify biomechanical, musculoskeletal, physiological, and nutritional risk factors for injury in USASOC Operators**
Data collection ongoing.

**Phase 2 Aim 2: To determine the relationship between previous history of unintentional musculoskeletal injury and biomechanical, musculoskeletal, physiological, and tactical characteristics**
Multiple analyses were performed to identify the impact of previous musculoskeletal injury on musculoskeletal characteristics. Musculoskeletal injuries were self-reported from the time of enlistment to the test date. A total of 168 were included in these analyses. Data were filtered to eliminate subjects with bilateral injuries to a single region. Laboratory data included body composition, shoulder strength and flexibility, and knee strength and flexibility. Two separate analyses were performed to analyze the data in all USASOC personnel tested and reduced to 18 series Operators including bilateral comparisons of the healthy groups, healthy group right limb and injured group injured limb, and healthy group right limb and injured group uninjured limb. The proportion of individual bilateral differences (> 10% difference) was calculated for each group and variable.

**USASOC**

**Low Back: Healthy- 118, Injured- 30**
No significant demographic differences were demonstrated between groups ($p > 0.05$). Subjects with a self-reported history of low back pathology demonstrated a higher body fat % than healthy subjects (20.9 ± 7.0 %, 18.1 ± 6.4%, $p = 0.045$). No significant strength differences were demonstrated between the injured and uninjured groups ($p > 0.05$). Insufficient torso extension/flexion ratios (< 1.3) were identified in 23.7% of healthy subjects and 33.3% of injured subjects.

**Knee: Healthy- 71, Injured- 34**
No significant demographic differences were demonstrated between groups ($p > 0.05$). No significant strength ($p > 0.05$) or flexibility ($p > 0.05$) differences were demonstrated between the injured and uninjured groups. Knee flexion/extension strength ratio was higher in the healthy group (0.57 ± 0.09) compared to the injured (0.52 ± 0.08, $p = 0.023$) and uninjured (0.53 ± 0.12, $p = 0.011$) limbs of the injured group. Statistical bilateral differences in the healthy group were demonstrated for knee extension strength (R: 224.7 ± 45.1 %BW, L: 216.6 ± 38.4 %BW) and hamstring flexibility (R: 16.9 ± 9.3°, L: 19.8 ± 8.5°, $p < 0.001$). Individual bilateral differences for knee flexion strength were identified in 41% of healthy subjects and 35.3% of injured subjects. Individual bilateral differences for knee extension strength were identified in 43.7% of healthy subjects and 26.5% of injured subjects. Insufficient knee flexion/extension strength ratios were identified in 42.3-46.5% of healthy subjects and 64.7-67.6% of injured subjects.

**Shoulder: Healthy- 77, Injured- 38**

Subjects with a prior shoulder injury were older (36.2 ± 7.4 years) compared to the healthy subjects (32.3 ± 6.2 years, p = 0.009). Internal rotation strength of the healthy subjects (57.5 ± 12.3 %BW) was significantly higher compared to the injured (52.5 ± 10.9 %BW, p = 0.022) and uninjured (53.4 ± 10.8 %BW, p = 0.033) limbs of the injured group. The external rotation/internal rotation strength ratio was significantly lower in the healthy subjects (0.682 ± 0.139) compared to the injured (0.745 ± 0.155, p = 0.035) and uninjured (0.737 ± 0.126, p = 0.025) limbs of the injured group. Individual bilateral differences for internal rotation strength were identified in 42.9% of healthy and 42.1% of injured subjects. Individual bilateral differences for external rotation strength were identified in 36.4% for healthy subjects and 28.9% of injured subjects. Insufficient external rotation/internal rotation strength ratios were identified in 29.9-42.0% of healthy subjects and 28.9% of injured subjects. Internal rotation flexibility was significantly different within the healthy group (R: 61.1 ± 10.1°, L: 58.5 ± 11.4°, p = 0.009). Posterior shoulder tightness was significantly different between the injured and uninjured limb of the injured group (Injured: 111.0 ± 8.7°, Uninjured: 114.1 ± 8.8°, p = 0.001).

**18 Series Operators**
**Low Back: Healthy- 86, Injured- 20**
No significant demographics differences were demonstrated between groups (p > 0.05). No significant strength differences were demonstrated between the healthy and injured groups (p > 0.05). Insufficient extension/flexion ratios were identified in 18.6% of healthy subjects and 30% of injured subjects.

**Knee: Healthy- 51, Injured- 24**
No significant demographic differences were demonstrated between groups (p > 0.05). Knee extension strength was significantly different between limbs of the healthy group (R: 231.6 ± 42.4 %BW, L: 224.7 ± 36.4 %BW, p = 0.029). No significant between group differences were demonstrated (p > 0.05). Individual bilateral differences for knee flexion strength were identified in 45.1% of healthy subjects and 25% of injured subjects. Individual bilateral differences for knee extension were identified in 43.1% of healthy subjects and 25% of injured subjects. Insufficient knee flexion/extension ratio was identified in 43.1% of healthy subjects and 66.6-70.8% of injured subjects. Bilateral hamstring flexibility was significantly different between limbs of the healthy group (R: 17.6 ± 9.2°, L: 20.5 ± 8.2°, p < 0.001).

**Shoulder: Healthy- 53, Injured- 29**
Subjects with a prior shoulder injury were older (36.0 ± 7.3 years) compared to the healthy subjects (31.4 ± 5.8 years, p = 0.003). Internal rotation strength of the healthy subjects was significantly higher (60.8 ± 11.5 %BW) compared to the injured (54.5 ± 10.5 %BW, p = 0.05) and uninjured limbs (55.5 ± 11.3 %BW, p = 0.014) of the injured group. The external rotation/internal rotation strength ratio was significantly lower in the healthy subjects (0.653 ± 0.122) compared to the injured (0.724 ± 0.121, p = 0.026) and uninjured (0.724 ± 0.124, p = 0.018) limbs of the injured group. Individual bilateral differences for internal rotation strength were identified in 45.3% of healthy and 44.8% of injured subjects. Individual bilateral differences for external rotation strength were identified in 35.8% for healthy subjects and 34.5% of injured subjects. Insufficient external rotation/internal rotation strength ratios were identified in 35.8-49.1% of healthy subjects and 31.0-34.5% of injured subjects. Internal rotation flexibility was significantly different within the healthy group (R: 60.9 ± 9.8°, L: 58.4 ± 11.3°, p = 0.040). Posterior shoulder tightness was significantly different between the injured and uninjured limb of the injured group (Injured: 111.6 ± 9.4°, Uninjured: 114.4 ± 9.3°, p = 0.008).

**Summary:**
Few physical differences exist between Operators with prior musculoskeletal injury and those with no prior injury suggesting complete rehabilitation allowing return to unrestricted tactical and physical activities. A review of the raw subject data within the prior musculoskeletal injury group and no prior injury group revealed a high proportion of subjects demonstrating a bilateral asymmetry > 10% regardless if they presented with a prior injury. This threshold is critical to the prevention of musculoskeletal injury and optimizing physical readiness. The data suggest that despite return to active duty performance following an injury, or healthy, large cohorts of subjects present with musculoskeletal asymmetries that may predispose the Operator to additional injury. The data also suggest that a high proportion of those subjects demonstrated asymmetrical findings similar and these individuals may be at risk for developing

future musculoskeletal injury. Both of these scenarios may limit physical readiness at the individual and unit level.

**Phase 2 Aim 3: To identify suboptimal biomechanical, musculoskeletal, physiological, tactical, and nutritional characteristics for physical readiness in the USASOC Operator**
Data collection ongoing. To date testing has been completed on 231 personnel.

**Subject Demographics**

| | Age (Years) | Height (Inches) | Weight (Pounds) |
|---|---|---|---|
| USASOC (All) | 32.3 ± 6.7 | 70.5 ± 2.7 | 188.7 ± 25.9 |
| 18 Series (3/5 SFG) | 31.5 ± 5.2 | 70.5 ± 2.3 | 187.8 ± 23.6 |
| SWCS (18 Series) | 39.8 ± 7.7 | 71.0 ± 2.4 | 190.2 ± 24.7 |
| Q-Course | 28.6 ± 3.2 | 72.1 ± 2.3 | 185.0 ± 23.1 |
| Pre Q-Course | 23.5 ± 2.5 | 69.2 ± 4.7 | 177.9 ± 39.7 |
| Support | 33.9 ± 6.5 | 71.0 ± 2.6 | 191.1 ± 23.0 |
| Other | 36.0 ± 6.9 | 70.1 ± 2.2 | 193.3 ± 26.4 |

**Nutritional Profiles**
A nutritional analysis was performed for each subject through a nutrition/exercise history interview and a self-reported 24 hour dietary recall. Nutrition history included weight/body composition goals, physical training, eating habits, fluid consumption, frequency of foods, and supplement usage. Food/fluid habits relative to daily food consumption, prior to, during, and after physical training were compared to the profiles of an athletic population under similar physical demands. Data were analyzed to determine if the nutritional needs of operators were met in reference to total energy consumption, macronutrient distribution, and eating/hydration habits during physical training. Additionally, frequency of supplement usage and type were reported.

## Energy Requirements for Physical Training and Weight Goals

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

**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 operators weight and body composition 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 methods used to obtain the data. Although the daily total energy expenditure (TEE) of the students 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.

**Weight Goals and Energy Intake**

| | USASOC Average BF 13.7±5.1% | 3SFG Average BF 13.5±4.7% | QCourse Average BF 11.8±4.6% | SWCS Average BF NA | Pre QCourse Average BF 14.7±4.1% |
|---|---|---|---|---|---|
| ***Want to gain weight*** | 15% | 17% | 38% | 0% | 30% |
| Consuming excess calories for weight gain | 29% | 33% | 0% | -- | 50% |
| Consuming adequate calories to maintain weight | 26% | 22% | 33% | -- | 17% |
| NOT consuming adequate calories to meet needs | 45% | 45% | 67% | -- | 33% |

| | USASOC Average BF 22.0±6.4% | 3SFG Average BF 20.1±6.1% | QCourse Average BF NA | SWCS Average BF 23.7±7.1% | Pre-QCourse Average BF 17.2±4.9% |
|---|---|---|---|---|---|
| ***Want to lose weight*** | 41% | 43% | 0% | 56% | 20% |
| Consuming adequate calories for weight loss | 57% | 55% | -- | 67% | 50% |
| Consuming adequate calories to maintain weight | 19% | 16% | -- | 11% | 25% |
| Consuming excess calories | 24% | 29% | -- | 22% | 25% |

| | USASOC Average BF | 3SFG Average BF | QCourse Average BF | SWCS Average BF | Pre-QCourse Average BF |
|---|---|---|---|---|---|

| | 16.6± 5.7% | 14.8±6.4% | 12.6±6.9% | 20.3±7.6% | 18.3±5.4% |
|---|---|---|---|---|---|
| ***Want to maintain current weight*** | 37% | 34% | 62% | 44% | 50% |
| Consuming adequate calories for weight maintenance | 20% | 25% | 0% | 17% | 20% |
| Consuming excess calories | 33% | 28% | 40% | 0% | 40% |
| NOT consuming adequate calories to meet needs | 47% | 47% | 60% | 83% | 40% |

**Summary:**
In order to gain weight, caloric intake must exceed daily total energy expenditure. Only a portion of Operators indicating a desire for weight gain consumed excess calories above nutritional requirements to fuel estimated energy needs. In fact, many Operators are not consuming adequate calories to maintain their current weight. Nearly half of these Operators are under consuming calories to meet basic needs and are instead promoting an environment for weight loss.

An environment in which total daily energy expenditure exceeds caloric intake is required to promote weight loss. Just over half of the Operators indicating a desire to lose weight were consuming adequate calories in order to do so. A portion of Operators were consuming the necessary amount of calories for weight maintenance and some, in excess. Consuming excess calories counter act the ability of the Operator to meet their goal of weight loss. These Operators should seek the advice of a Registered Dietitian to safely guide them through a meal plan to reach their goals while adequately fueling the demands of physical training.

Weight maintenance requires energy balance – total estimated energy expenditure is equal to caloric intake. Only a portion of Operators indicating a desire for weight maintenance consumed adequate calories to meet their estimated energy needs. Over a third of Operators were instead consuming excess calories which would promote weight gain. Nearly half of these Operators are not meeting energy needs, suggesting weight loss, impairment to physical performance, and increased risk for injury and illness.

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

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

## Carbohydrate Requirements for Physical Training

**Testing methodology:**
Nutrition History and 24 hour Diet Recall

**Purpose:**
Carbohydrates should be provided based on training time and body weight in order to individualize specific muscle fuel needs for the Operators. 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 Operators are able to perform maximally and are combat ready more quickly.

**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.

Carbohydrate requirements will be estimated based physical training using the following:

| Grams Carbohydrate/kg body weight/day | Training |
|---|---|
| 4-5 g/kg/day | Typical US Diet (low activity) |
| 5-7 g/kg/day | General training activities |
| 7-10 g/kg/day | Endurance athletes |
| 10-12 g/kg/day | Ultra endurance exercise (4-6 hr/day) |

**Data and Results:**

| **Carbohydrate Requirements for Physical Training** | USASOC | 3SFG | QCourse | SWCS | Pre-QCourse |
|---|---|---|---|---|---|
| Met or exceeded the amount of carbohydrate in a typical US Diet (4-5 g/kg body weight/day) | 30% | 30% | 25% | 19% | 50% |
| Met or exceeded the recommended amount of carbohydrate for general training needs (5-7 g/kg body weight/day) | 17% | 17% | 25% | 6% | 35% |

**Summary:**
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 Operators to train at a higher level, it is vital they consume sufficient carbohydrates on a daily basis. The majority of Operators tested are currently not meeting the recommended amount of carbohydrate to optimally replace muscle glycogen or fuel muscles for higher intensity longer duration physical training.

## Protein Requirements for Increasing Muscular Strength and Endurance

**Testing Methodology:**
Nutrition History and 24 hour Diet Recall

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

**Background:**
A protein intake of 1.2-1.7 g/kg body weight 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.

<u>Protein Requirements</u>: 1.2-1.7 g/kg body weight for endurance to strength trained athletes

**Data and Results:**

| **Protein Requirements for Increasing Muscular Strength and Endurance** | USASOC | 3SFG | QCourse | SWCS | Pre-QCourse |
|---|---|---|---|---|---|
| Fell within recommended protein requirements (1.2-1.7g/kg bw/day) | 31% | 38% | 13% | 19% | 15% |
| Fell below recommended range for protein requirements <1.2 g/kg bw/day | 34% | 26% | 25% | 50% | 30% |
| Exceeded recommended range for protein requirements (>1.8 g/kg bw/day) | 31% | 30% | 63% | 25% | 55% |

**Summary**:
There is a relatively even distribution among Operators who are meeting, falling below, or exceeding the range for protein requirements. Consuming between 1.2 and 1.7g per kg of body mass should adequately meet protein needs during strenuous physical training. Those Operators falling below the recommended range for protein intake are at risk for decreased body mass, muscle strength, size, and power output. For those Operators exceeding the recommended range for protein intake, excess protein may be replacing the intake of carbohydrates needed to properly fuel working muscle.

**Data and Results:**

| **Protein Requirements for Increasing Muscular Strength and Endurance** | USASOC | 3SFG | QCourse | SWCS | Pre-QCourse |
|---|---|---|---|---|---|
| Met protein requirements, exceeded estimated energy needs | 4% | 6% | 0% | 0% | 5% |
| Met/exceeded protein needs, did NOT meet | 42% | 47% | 50% | 44% | 10% |

| | | | | | |
|---|---|---|---|---|---|
| estimated energy needs | | | | | |
| Fell below recommended protein range, did NOT consume adequate calories | 34% | 26% | 25% | 44% | 30% |

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 – very few Operators are meeting these requirements. Additionally, nearly half of these Operators were not meeting estimated 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

**Testing Methodology:**
Nutrition History and 24 hour Diet Recall

**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 fat/kg body weight (moderate PT) to 2.0 g fat/kg body weight (heavy PT longer duration >4 hours/day).

**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/kg body weight based on caloric needs, body composition goals and duration and intensity of training.

**Data and Results:**

| **Distribution of Fat in the Diet** | USASOC | 3SFG | QCourse | SWCS | Pre-QCourse |
|---|---|---|---|---|---|
| Consumed within recommended range for fat intake (0.8g to ≤ 2.0g/kg/day) | 62% | 68% | 75% | 38% | 45% |
| Consumed less than 0.8g fat/kg body weight/day | 27% | 26% | 13% | 56% | 15% |
| Exceeded 2.0g fat/kg body weight/day | 10% | 7% | 13% | 6% | 40% |
| Exceeded estimated energy requirements w/ highest fat consumption | 12% (1.59-4.7g fat/kg) | 10% (1.59-3.25g fat/kg) | 13% (2.75g fat/kg) | -- | 30% (1.66-4.7g fat/kg) |

**Summary:**
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 Operators 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.

The majority of Operators fell within the recommended range for fat intake. Those operators 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 Dietary Reference Intakes (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.

**Data and Results:**

| **Distribution of Fat in the Diet** | USASOC | 3SFG | QCourse | SWCS | Pre-QCourse |
|---|---|---|---|---|---|
| Consumed greater than 30% of calories from fat | 66% | 70% | 88% | 50% | 70% |

**Summary:**

The majority of Operators are currently consuming a diet that is >30% of calories from fat. High fat diets increase the risk for overweight, 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**

**Testing Methodology:** Nutrition History

**Purpose:** Examine fluid habits before, during and after exercise

**Background:**
The goal is to provide adequate fluids to avoid dehydration but not in excess to avoid water intoxication. The Operator 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/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.

**Data and Results:**

| **Consumed Fluids** | USASOC | 3SFG | QCourse | SWCS | Pre-QCourse |
|---|---|---|---|---|---|
| Before Physical Training | 89% | 91% | 0% | 88% | 85% |
| During Physical Training | 77% | 82% | 88% | 71% | 95% |
| After Physical Training | 100% | 97% | 88% | 100% | 95% |

| **Type of Fluids Before PT** | USASOC | 3SFG | QCourse | SWCS | Pre-QCourse |
|---|---|---|---|---|---|
| Water | 80% | 80% | 0% | 87% | 100% |
| Other | 15% (coffee, low fat milk, fruit juice) | 16% (coffee, low fat milk, fruit juice) | 0% | 13% (coffee) | 5% |
| Sports Drinks | 4% | 4% | 0% | 0% | 29% |

| **Fluids During PT** | USASOC | 3SFG | QCourse | SWCS | Pre-QCourse |
|---|---|---|---|---|---|
| Water | 92% | 93% | 100% | 92% | 100% |
| Sports Drinks | 4% | 3% | 0% | 8% | 11% |
| Other | 3% | 3% | 0% | 0% | 0% |

| **Fluids After PT** | USASOC | 3SFG | QCourse | SWCS | Pre-QCourse |
|---|---|---|---|---|---|
| Water | 87% | 90% | 100% | 94% | 79% |
| Other | 9% | 11% (protein drink, fruit juice, coffee) | 0% | 0% | 21% |
| Sports Drinks | 3% | 3% | 0% | 12% | 26% |

**Summary**:
The majority of Operators consume some fluid before physical training. The beverage of choice is water followed by “other” drinks. The majority of Operators 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 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, 10-20 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.

The majority of Operators consumed fluids following physical training. Most drank water, followed by "other" drinks. Ideally, the beverage following physical training should contain fluid, 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 and rehydration.

**Timing and Type of Post Physical Training Protein Intake**

**Testing Methodology:**
Nutrition History and 24 hour Diet Recall

**Purpose:** Examine protein intake and timing after physical training

**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 muscle mass is gradually increased. 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 sustained higher physical work capacity (strength and endurance) in subsequent periods of exertion, thus increasing combat readiness.

**Data and Results**

| **Timing and Content of Pre-Training Snack** | USASOC | 3SFG | QCourse | SWCS | Pre-QCourse |
|---|---|---|---|---|---|
| Consumed pre-training meal or snack | 48% | 43% | 88% | 71% | 65% |
| **Pre-Training Type of Snack/Meal** | | | | | |
| Contained both CHO and PRO | 58% | 60% | 43% | 58% | -- |
| Contained only PRO | 9% | 9% | 14% | 8% | -- |
| Contained only CHO | 31% | 28% | 43% | 33% | -- |
| N/A | 2% | 4% | -- | -- | -- |

| **Timing of Pre-Training Snack/Meal** | USASOC | 3SFG | QCourse | SWCS | Pre-QCourse |
|---|---|---|---|---|---|
| < 30 min prior to PT | 26% | 21% | 43% | 25% | 23% |
| 30-60 min prior to PT | 58% | 68% | 43% | 42% | 77% |
| 1-2 hours prior to PT | 13% | 11% | 14% | 25% | 0% |
| 2-3 hours prior to PT | 2% | 0% | 0% | 8% | 0% |
| 3-4 hours prior to PT | 1% | 0% | 0% | 0% | 0% |

| **Timing and Content of Post-Training Snack/Meal** | USASOC | 3SFG | QCourse | SWCS | Pre-QCourse |
|---|---|---|---|---|---|
| Consumed post-training snack/meal | 91% | 84% | 100% | 94% | 85% |
| **Post-Training Type of Snack/Meal** | | | | | |
| Contained both CHO and PRO | 83% | 84% | 63% | 94% | -- |
| Contained only PRO | 13% | 12% | 37% | 6% | -- |
| Contained only CHO | 4% | 4% | -- | -- | -- |

| **Timing of Post-Training Snack/Meal** | USASOC | 3SFG | QCourse | SWCS | Pre-QCourse |
|---|---|---|---|---|---|
| < 30 min post PT | 49% | 50% | 50% | 50% | 52% |
| 30-60 min post PT | 46% | 48% | 25% | 44% | 47% |
| 1-2 hours post PT | 3% | 2% | 25% | 0% | 0% |
| 2-3 hours post PT | 1% | 0% | 0% | 6% | 0% |
| 3-4 hours post PT | 1% | 0% | 0% | 0% | 0% |

**Summary**:

Consuming food prior to PT will provide additional energy and may help to delay fatigue, allowing an Operator 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 of Operators report eating a snack or a meal after the completion of physical training. Many consumed a snack/meal that contained both carbohydrate and protein. Ideally, consuming food that contains a moderate amount of carbohydrate and a small amount of protein within 30 minutes of activity will expedite muscle glycogen resynthesis and help to reduce muscle protein breakdown. This is especially important for those Operators/students/instructors participating in subsequent training bouts within 8 hours.

**Dietary Supplement Usage**

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

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

**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.

**Data and Results**

| | USASOC | 3SFG | QCourse | SWCS | Pre-QCourse |
|---|---|---|---|---|---|
| **Operators that Report Taking at Least One Dietary Supplement** | 74% | 76% | 63% | 76% | 94% |

| **Breakdown of Dietary Supplements** | USASOC | 3SFG | QCourse | SWCS | Pre-QCourse |
|---|---|---|---|---|---|
| Whey/Protein Supplements | 19% | 20% | 21% | 11% | 57% |
| Energy Drinks/Caffeine | 3% | 2% | 4% | 2% | 0% |
| BCAA, Amino Acids | 10% | 10% | 17% | 4% | 9% |
| Fish Oil, Omega 3 FA, Antioxidants | 15% | 13% | 21% | 20% | 4% |
| Glucosamine, Chondroitin, Joint Stability | 7% | 7% | 8% | 4% | 13% |
| Creatine | 4% | 5% | 0% | 9% | 0% |
| Pre-workout (Jack 3D/C4 Nitric Oxide, NO Explode) | 5% | 6% | 0% | 11% | 0% |
| Weight Loss, CLA | 1% | 1% | 4% | 0% | 0% |
| Testosterone Boosters | 1% | 2% | 0% | 0% | 0% |
| Multivitamin/Minerals | 30% | 26% | 25% | 33% | 17% |
| Carbohydrate Gels/Recovery | 6% | 8% | 0% | 2% | 0% |
| Herbal Supplements, Probiotics | 1% | 1% | 0% | 2% | 0% |

The results of our survey indicate that of the majority of Operators indicate taking at least one dietary supplement, the most popular being a vitamin/mineral. A high percentage of operators are consuming a protein supplements, including Whey and/or BCAA. Consuming a meal with protein and carbohydrate before and after hard physical training will help to provide/replace used fuel stores and help rebuild muscle more rapidly. A small percentage of Operators reported consuming a pre-workout supplement, such as 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 contain Geranium Stem extract, 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).

Caution should be taken when consuming any dietary supplement, even vitamins/minerals. There is little, if any, regulation by the United States government on ingredients and formulas. A well balanced diet rich in fruits, vegetables, whole grains, lean protein, and healthy fats should provide adequate nutrients so that a dietary supplement is not needed.

**Nutrition Summary**

The majority of Operators tested did not meet the recommended amount of carbohydrate to optimally fuel 90-120 minutes of daily hard physical training (PT) and to restore muscle fuel for consecutive days of PT. Further, many Operators did not consume the recommended amount of carbohydrates for the (low active) "average adult male". Most Operators met the estimated protein requirements necessary to increase muscle size and strength. Over half of Operators consumed a diet that had >30% of calories from fat. 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 and put Operators at risk for developing excess body fat. The majority of Operators consume fluids before, during, and after physical training. Similarly, a high percentage of Operators are consuming a meal or snack upon completion of physical training. Ideally, this meal or snack should contain both carbohydrate and a small amount of protein and be consumed within thirty minutes following exercise to expedite muscle glycogen resynthesis and reduce muscle protein breakdown. Only half of the Operators reported consuming a recovery snack/meal within 30 minutes following PT. The reported meal/snack did contain both carbohydrate and protein. Dietary supplement use was reported in 74% the Operators. Popular dietary supplements consumed include multivitamin/mineral, protein supplements, and fish oil/antioxidant supplements. A small percentage of Operators reported consuming some type of pre-workout supplement (including Jack-3D, C4, or NO-Explode). The effectiveness of these pre-workout supplements as ergogenic aids is not supported by scientific literature nor have safety issues been adequately addressed in the athletic or military populations. Based on self-reported dietary intake, the current data indicates a suboptimal macronutrient distribution to fuel and recover from daily hard PT. To optimize the adaptations from PT, it is recommended to increase daily carbohydrate intake and decrease fat, especially saturated fat. This will provide more energy to the Operator during PT and reduce the reliance on pre-workout aids and other dietary supplements that may be harmful.

**Musculoskeletal, Physiological, and Biomechanical Profiles**
Subjects enrolled in the study underwent a comprehensive human performance assessment for injury prevention and optimal physical readiness to evaluate biomechanical, musculoskeletal, physiological, and nutritional characteristics relative to injury and performance. Specific testing included musculoskeletal strength and flexibility, balance, aerobic capacity and lactate threshold, anaerobic power and capacity, body composition, movement patterns during functional (tactical) tasks, nutritional history, and injury history. The following section details the results of data collection for musculoskeletal (strength, flexibility, balance), physiological, and biomechanical characteristics.

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

**Testing Methodology:**
Biodex System 3 isokinetic dynamometer (Biodex Medical, Shirley, NY)
5 repetitions
Average peak torque/body weight (BW)

**Purpose:** Examine rotator cuff strength

**Background:** Proper IR and ER rotator cuff strength is critical for the performance of demanding overhead tasks and maneuvers involving the upper extremity, and is critical for the prevention of shoulder injury. The glenohumeral joint is dependent upon the health of the rotator cuff as a source of dynamic joint stabilization. Deficiencies in strength or reciprocal balance of the rotator cuff musculature will predispose the shoulder joint to altered kinematics, leading to acute and/or chronic joint instability, impingement syndromes, and rotator cuff tears. Further, shoulder IR and ER strength testing consistently detects persistent and potentially dangerous rotator cuff weakness after previous injury.

**Data and Results:**

**RIGHT**

| | IR (% BW) | ER (% BW) | ER/IR (Ratio) |
|---|---|---|---|
| Top 10th %tile 3SFG | 78.1 | 49.3 | -- |
| Top 25th %tile 3SFG | 68.5 | 44.7 | -- |
| 50th %tile 3SFG | 61.8 | 38.6 | -- |
| Bottom 25th %tile 3SFG | 53.5 | 35.4 | -- |
| Athlete* | 53.0 ± 12.0 | 40.0 ± 10.0 | 0.77 ± 0.16 |
| Triathletes | 64.3 ± 9.7 | 46.5 ± 6.9 | 0.73 ± 0.09 |
| USASOC (All) | 57.5 ± 12.5 | 38.4 ± 7.1 | 0.69 ± 0.15 |
| 18 Series (3/5 SFG) | 61.4 ± 12.5 | 40.1 ± 7.5 | 0.67 ± 0.15 |
| SWCS (18 Series) | 56.6 ± 6.6 | 39.0 ± 6.4 | 0.70 ± 0.15 |
| Q-Course | 52.7 ± 12.4 | 38.7 ± 5.1 | 0.78 ± 0.25 |
| Pre Q-Course | 56.0 ± 10.9 | 37.4 ± 5.8 | 0.68 ± 0.11 |
| Support | 51.9 ± 13.4 | 36.4 ± 6.1 | 0.72 ± 0.15 |
| Other | 53.2 ± 10.7 | 35.0 ± 6.7 | 0.66 ± 0.15 |

**LEFT**

| | IR (% BW) | ER (% BW) | ER/IR (Ratio) |
|---|---|---|---|
| Top 10th %tile 3SFG | 79.8 | 48.9 | -- |
| Top 25th %tile 3SFG | 65.5 | 43.1 | -- |
| 50th %tile 3SFG | 57.3 | 38.2 | -- |
| Bottom 25th %tile 3SFG | 49.4 | 35.2 | -- |
| Athlete* | 53.0 ± 12.0 | 40.0 ± 10.0 | 0.77 ± 0.16 |
| Triathletes | 65.5 ± 13.6 | 44.5 ± 7.3 | 0.69 ± 0.12 |
| USASOC (All) | 55.9 ± 12.5 | 37.1 ± 7.3 | 0.68 ± 0.13 |
| 18 Series (3/5 SFG) | 59.3 ± 13.2 | 39.4 ± 7.6 | 0.68 ± 0.13 |
| SWCS (18 Series) | 57.9 ± 9.0 | 39.5 ± 3.5 | 0.69 ± 0.11 |
| Q-Course | 54.0 ± 7.6 | 40.5 ± 8.0 | 0.76 ± 0.10 |
| Pre Q-Course | 53.4 ± 11.0 | 33.3 ± 5.4 | 0.62 ± 0.11 |
| Support | 49.4 ± 11.2 | 34.2 ± 6.2 | 0.71 ± 0.13 |
| Other | 52.5 ± 11.2 | 33.2 ± 5.8 | 0.65 ± 0.13 |

***Male collegiate swimmers (Oyama, 2006).**

Compared to the normative threshold, 14.3-50.0% of USASOC personnel demonstrated suboptimal performance for shoulder internal rotation strength, 21.4-66.7% for shoulder external rotation strength, and 33.3-71.4% for external rotation/internal rotation strength ratio. Bilateral asymmetry was identified in 53.8% of USASOC personnel for internal rotation strength and 39.6% for external rotation strength.

**Shoulder Protraction, Retraction and Elevation Strength**

**Testing Methodology:**
Biodex System 3 isokinetic dynamometer (Biodex Medical, Shirley, NY)
5 repetitions
Average peak torque/BW

**Purpose:** Examine scapular stabilizer strength

**Background:** Scapular stabilization strength is critical for the performance of demanding upper limb tasks. Scapular protractor, retractor, and elevation muscle performance is critical for shielding the shoulder complex from potentially injurious forces. The shoulder complex is dependent on the health of the scapular stabilizers as sources of dynamic joint stabilization. Deficiencies in strength or reciprocal balance of the scapular stabilizer musculature will predispose the shoulder complex to altered kinematics, leading to acute and/or chronic shoulder joint instability, shoulder impingement syndromes, rotator cuff tears, trapped nerves, and occluded blood supply throughout the arm. Further, shoulder protractor-retractor and elevation strength testing consistently detects persistent and potentially dangerous muscle weakness after previous upper limb injury.

**Data and Results:**

**RIGHT**

| | Protraction (% BW) | Retraction (% BW) | Pro/Ret (Ratio) | Upper Trapezius (% BW) |
|---|---|---|---|---|
| Top 10th %tile 3SFG | 612.3 | 646.7 | -- | 713.1 |
| Top 25th %tile 3SFG | 558.4 | 585.5 | -- | 653.7 |
| 50th %tile 3SFG | 461.2 | 479.8 | -- | 574.5 |
| Bottom 25th %tile 3SFG | 395.6 | 377.1 | -- | 486.5 |
| Athlete* | 494.0 ± 96.0 | 469.0 ± 80.0 | 1.18 ± 0.23 | -- |
| USASOC (All) | 442.3 ± 109.8 | 449.7 ± 126.6 | 1.01 ± 0.22 | 547.3 ± 108.0 |
| 18 Series (3/5 SFG) | 470.9 ± 110.2 | 476.0 ± 130.3 | 1.02 ± 0.23 | 566.1 ± 115.3 |
| SWCS (18 Series) | 426.9 ± 83.3 | 459.8 ± 115.9 | 0.97 ± 0.24 | 558.0 ± 80.5 |
| Q-Course | 427.4 ± 92.9 | 434.5 ± 112.2 | 1.03 ± 0.27 | 518.5 ± 88.0 |
| Support | 408.5 ± 80.7 | 421.0 ± 89.3 | 0.98 ± 0.15 | 515.6 ± 99.9 |
| Other | 382.9 ± 125.7 | 387.3 ± 134.6 | 1.04 ± 0.23 | 514.5 ± 94.2 |

**LEFT**

| | Protraction (% BW) | Retraction (% BW) | Pro/Ret (Ratio) | Upper Trapezius (% BW) |
|---|---|---|---|---|
| Top 10th %tile 3SFG | 591.9 | 680.8 | -- | 693.3 |
| Top 25th %tile 3SFG | 528.3 | 604.2 | -- | 632.5 |
| 50th %tile 3SFG | 441.3 | 509.1 | -- | 572.4 |
| Bottom 25th %tile 3SFG | 354.6 | 419.7 | -- | 484.1 |
| Athlete* | 494.0 ± 96.0 | 469.0 ± 80.0 | 1.18 ± 0.23 | -- |
| USASOC (All) | 404.7 ± 108.1 | 467.6 ± 140.2 | 0.90 ± 0.26 | 537.7 ± 104.8 |
| 18 Series (3/5 SFG) | 440.7 ± 112.9 | 502.2 ± 143.0 | 0.92 ± 0.29 | 559.3 ± 106.3 |
| SWCS (18 Series) | 354.8 ± 81.4 | 429.4 ± 144.3 | 0.90 ± 0.34 | 541.1 ± 81.6 |
| Q-Course | 366.1 ± 131.0 | 426.8 ± 147.8 | 0.88 ± 0.24 | 521.4 ± 90.1 |
| Support | 355.6 ± 73.8 | 421.5 ± 97.1 | 0.85 ± 0.12 | 517.0 ± 102.8 |
| Other | 362.5 ± 76.9 | 421.4 ± 140.7 | 0.91 ± 0.18 | 479.6 ± 96.4 |

***Protraction and Retraction: Healthy overhead athletes (Cools, 2005). Protraction/Retraction Ratio: Top 10$^{th}$ Percentile of SBT-22.**

Compared to the normative threshold, 43.3-87.5% of USASOC personnel demonstrated suboptimal performance for shoulder protraction strength, 35.7-62.5% for shoulder retraction strength, and 66.0-96.7% for protraction/retraction strength ratio. Bilateral asymmetry was identified in 56.7-87.5% of USASOC personnel for protraction strength and 37.5-70.8% for retraction strength.

## Torso Flexion and Extension Strength

**Testing Methodology:**
Biodex System 3 isokinetic dynamometer (Biodex Medical, Shirley, NY)
5 repetitions
Average peak torque/BW

**Purpose:** Examine flexion and extension torso strength

**Background:** Adequate torso muscle strength is important for the safe, efficient, and effective performance of virtually all demanding upper limb, lower limb, and whole-body tasks. Spinal muscle performance is critical for shielding the lower back's anatomical structures and connective tissues from potentially injurious forces. The lower back bones, discs, joints, nerves, and blood vessels are dependent on the health of the torso muscles as sources of dynamic joint stabilization and tissue stress-shields. Deficiencies in strength or reciprocal balance of the torso musculature may lead to injury to the lower back. Moreover, torso strength testing may reveal persistent torso muscle weakness after traumatic and overuse lower back injury which could lead to future injury.

**Data and Results:**

| | Flexion (% BW) | Extension (% BW) | Flex/Ext (Ratio) |
|---|---|---|---|
| Top 10th %tile 3SFG | 231.4 | 426.2 | -- |
| Top 25th %tile 3SFG | 214.8 | 355.7 | -- |
| 50th %tile 3SFG | 194.0 | 298.7 | -- |
| Bottom 25th %tile 3SFG | 169.3 | 260.4 | -- |
| Athlete* | 280.0 ± 40.0 | 650.0 ± 120.0 | -- |
| Triathletes | 238.9 ± 40.9 | 415.0 ± 96.7 | 1.75 ± 0.34 |
| USASOC (All) | 191.1 ± 34.1 | 293.5 ± 76.0 | 1.55 ± 0.35 |
| 18 Series (3/5 SFG) | 193.0 ± 35.0 | 312.2 ± 78.7 | 1.63 ± 0.38 |
| SWCS (18 Series) | 190.8 ± 33.1 | 284.9 ± 30.0 | 1.54 ± 0.33 |
| Q-Course | 203.7 ± 43.6 | 310.9 ± 86.0 | 1.53 ± 0.23 |
| Pre Q-Course | 188.3 ± 35.5 | 272.2 ± 76.3 | 1.45 ± 0.32 |
| Support | 191.2 ± 31.7 | 271.2 ± 79.2 | 1.41 ± 0.34 |
| Other | 182.7 ± 30.8 | 269.2 ± 60.5 | 1.48 ± 0.25 |

***Flexion and Extension: Collegiate male wrestlers (Iwai, 2008). Extension/Flexion Ratio: Healthy adults (Smith, 1985).**

Compared to the normative threshold, 66.7-97.1% of USASOC personnel demonstrated suboptimal performance for torso flexion strength, 100% for torso extension strength, and 44.4-71.6% for external rotation/internal rotation strength ratio.

**Knee Flexion and Extension Strength**

**Testing Methodology:**
Biodex System 3 isokinetic dynamometer (Biodex Medical, Shirley, NY)
5 repetitions
Average peak torque/BW

**Purpose:** Examine knee flexion and extension strength

**Background:** Adequate strength of the hamstring and quadriceps muscle groups is vital for the safe and effective performance of potentially injurious landing tasks and change-of-direction maneuvers associated with tactical operations and physical training. These muscle groups contribute to the dissipation of imposed forces and neuromuscular control 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 lower extremity injuries during training.

**Data and Results:**

**RIGHT**

| | Flexion (% BW) | | | Extension (% BW) | | | Flex/Ext (Ratio) | | |
|---|---|---|---|---|---|---|---|---|---|
| Top 10th %tile 3SFG | 171.4 | | | 297.1 | | | -- | | |
| Top 25th %tile 3SFG | 150.4 | | | 268.4 | | | -- | | |
| 50th %tile 3SFG | 130.3 | | | 246.2 | | | -- | | |
| Bottom 25th %tile 3SFG | 119.4 | | | 212.8 | | | -- | | |
| Athlete* | 170.0 | ± | 22.0 | 270.0 | ± | 41.0 | 0.65 | ± | 0.11 |
| Triathletes | 128.0 | ± | 22.6 | 242.1 | ± | 50.4 | 0.55 | ± | 0.09 |
| Normative | -- | | | -- | | | 0.60 | - | 0.80 |
| USASOC (All) | 127.1 | ± | 24.2 | 233.7 | ± | 43.5 | 0.55 | ± | 0.10 |
| 18 Series (3/5 SFG) | 134.6 | ± | 23.7 | 243.6 | ± | 44.1 | 0.56 | ± | 0.10 |
| SWCS (18 Series) | 122.4 | ± | 13.8 | 227.9 | ± | 42.7 | 0.55 | ± | 0.10 |
| Q-Course | 128.0 | ± | 10.7 | 249.5 | ± | 21.1 | 0.51 | ± | 0.03 |
| Pre Q-Course | 118.9 | ± | 24.9 | 233.7 | ± | 42.8 | 0.52 | ± | 0.08 |
| Support | 117.6 | ± | 23.1 | 218.1 | ± | 45.4 | 0.54 | ± | 0.11 |
| Other | 119.0 | ± | 25.7 | 216.5 | ± | 36.1 | 0.54 | ± | 0.08 |

**LEFT**

| | Flexion (% BW) | Extension (% BW) | Flex/Ext (Ratio) |
|---|---|---|---|
| Top 10th %tile 3SFG | 164.7 | 288.9 | -- |
| Top 25th %tile 3SFG | 143.2 | 262.1 | -- |
| 50th %tile 3SFG | 129.6 | 229.0 | -- |
| Bottom 25th %tile 3SFG | 113.8 | 207.7 | -- |
| Athlete* | 170.0 ± 22.0 | 270.0 ± 41.0 | 0.65 ± 0.11 |
| Triathletes | 128.5 ± 23.2 | 241.3 ± 42.9 | 0.53 ± 0.06 |
| Normative | -- | -- | 0.60 - 0.80 |
| USASOC (All) | 122.6 ± 24.2 | 224.4 ± 42.2 | 0.55 ± 0.09 |
| 18 Series (3/5 SFG) | 130.5 ± 25.1 | 233.1 ± 41.5 | 0.56 ± 0.09 |
| SWCS (18 Series) | 121.5 ± 15.5 | 222.3 ± 32.9 | 0.55 ± 0.08 |
| Q-Course | 124.2 ± 13.4 | 234.2 ± 16.2 | 0.53 ± 0.09 |
| Pre Q-Course | 117.1 ± 22.3 | 226.0 ± 44.7 | 0.53 ± 0.09 |
| Support | 112.5 ± 22.6 | 204.5 ± 46.3 | 0.56 ± 0.10 |
| Other | 110.8 ± 20.2 | 213.8 ± 40.3 | 0.53 ± 0.06 |

***Rugby union players (Newman, 2004).**

Compared to the normative threshold, 77.5-100% of USASOC personnel demonstrated suboptimal performance for knee flexion strength, 44.4-83.3% for knee extension strength, and 46.0-88.9% for knee flexion/extension strength ratio. Bilateral asymmetry was identified in 28.6-55.6% of USASOC personnel for knee flexion strength and 33.3-50.0% for knee extension strength.

## Musculoskeletal Flexibility
## Shoulder Flexion and Extension

**Testing Methodology:**
Saunders Digital Inclinometer (The Saunders Group, Chaska, MN)
3 measures
Passive shoulder flexion and extension
Average of 3 joint angles (°)

**Purpose:** Examine shoulder flexion and extension flexibility

**Background:** Shoulder range of motion (ROM) is critical for maintenance of proper glenohumeral and shoulder girdle kinematics. A deficit in shoulder ROM will significantly impact overall performance during demanding overhead and upper extremity tasks and predispose the Operator to potentially traumatic and/or chronic pathologies.

**Data and Results:**

**RIGHT**

| | Flexion (degrees) | Extension (degrees) |
|---|---|---|
| Top 10th %tile 3SFG | 190.0 | 81.5 |
| Top 25th %tile 3SFG | 185.0 | 74.4 |
| 50th %tile 3SFG | 181.3 | 68.9 |
| Bottom 25th %tile 3SFG | 179.6 | 60.0 |
| Athlete* | 168.0 ± 8.7 | 81.0 ± 11.8 |
| Triathletes | 177.4 ± 10.9 | 69.2 ± 8.5 |
| Clinical Range | 170.0-190.0 | 50.0-70.0 |
| USASOC (All) | 182.1 ± 7.9 | 68.6 ± 11.6 |
| 18 Series (3/5 SFG) | 182.1 ± 7.5 | 67.5 ± 11.7 |
| SWCS (18 Series) | 181.6 ± 5.9 | 71.3 ± 8.1 |
| Q-Course | 184.0 ± 5.2 | 71.2 ± 6.6 |
| Support | 181.8 ± 10.8 | 71.6 ± 13.6 |
| Other | 181.8 ± 7.9 | 67.9 ± 11.3 |

**LEFT**

| | Flexion (degrees) | Extension (degrees) |
|---|---|---|
| Top 10th %tile 3SFG | 190.2 | 80.7 |
| Top 25th %tile 3SFG | 185.0 | 73.1 |
| 50th %tile 3SFG | 180.7 | 65.5 |
| Bottom 25th %tile 3SFG | 178.5 | 60.0 |
| Athlete* | 168.0 ± 8.7 | 81.0 ± 11.8 |
| Triathletes | 176.7 ± 10.7 | 71.4 ± 9.2 |
| Clinical Range | 170.0-190.0 | 50.0-70.0 |
| USASOC (All) | 181.3 ± 8.9 | 68.1 ± 11.3 |
| 18 Series (3/5 SFG) | 181.5 ± 8.6 | 66.4 ± 11.5 |
| SWCS (18 Series) | 181.7 ± 7.6 | 70.5 ± 7.8 |
| Q-Course | 185.5 ± 4.6 | 74.3 ± 8.2 |
| Support | 180.1 ± 9.6 | 71.8 ± 11.8 |
| Other | 180.6 ± 10.4 | 67.4 ± 11.2 |

***Non-dominant arm of professional baseball position players (Brown, 1988).**

Compared to the clinical range, up to 10.0% of USASOC personnel demonstrated suboptimal motion for shoulder flexion and 9.4% for shoulder extension.

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

**Testing Methodology:**
Saunders Digital Inclinometer (The Saunders Group, Chaska, MN)
3 measures
Passive shoulder external rotation, internal rotation, and posterior shoulder tightness
Average of 3 joint angles (°)

**Purpose:** Examine shoulder external (ER) and internal rotation (IR) and Posterior Shoulder Tightness (PST) flexibility

**Background:** A balance between ER and IR flexibility is desired to maintain appropriate glenohumeral joint kinematics and contributes to better physical performance during overhead activities. Posterior shoulder tightness (PST) 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.

**Data and Results:**

**RIGHT**

| | External Rotation (degrees) | Internal Rotation (degrees) | PST (degrees) |
|---|---|---|---|
| Top 10th %tile 3SFG | 110.9 | 71.0 | 123.7 |
| Top 25th %tile 3SFG | 105.0 | 63.3 | 117.5 |
| 50th %tile 3SFG | 98.3 | 56.3 | 109.7 |
| Bottom 25th %tile 3SFG | 91.0 | 50.0 | 103.3 |
| Athlete* | 124.0 ± 12.7 | 91.0 ± 13.0 | 105.0 ± 11.4 |
| Triathletes | 111.8 ± 7.1 | 54.3 ± 9.1 | 109.7 ± 7.0 |
| Clinical Range | 90.0-110.0 | 50.0-65.0 | 100.0-120.0 |
| USASOC (All) | 98.6 ± 9.1 | 57.9 ± 10.8 | 109.9 ± 9.6 |
| 18 Series (3/5 SFG) | 98.7 ± 8.9 | 56.9 ± 11.0 | 110.1 ± 9.7 |
| SWCS (18 Series) | 92.8 ± 5.1 | 56.5 ± 9.5 | 111.9 ± 7.5 |
| Q-Course | 97.8 ± 13.3 | 54.5 ± 11.4 | 107.1 ± 5.3 |
| Pre Q-Course | 100.6 ± 9.4 | 63.1 ± 9.6 | 112.8 ± 13.1 |
| Support | 100.1 ± 7.7 | 58.4 ± 10.5 | 109.9 ± 8.9 |
| Other | 98.1 ± 10.4 | 59.3 ± 11.1 | 107.7 ± 9.2 |

**LEFT**

| | External Rotation (degrees) | Internal Rotation (degrees) | PST (degrees) |
|---|---|---|---|
| Top 10th %tile 3SFG | 108.6 | 70.2 | 124.0 |
| Top 25th %tile 3SFG | 102.0 | 65.3 | 118.0 |
| 50th %tile 3SFG | 95.0 | 60.0 | 110.0 |
| Bottom 25th %tile 3SFG | 90.0 | 54.0 | 105.0 |
| Athlete* | 124.0 ± 12.7 | 91.0 ± 13.0 | 105.0 ± 11.4 |
| Triathletes | 109.1 ± 8.6 | 62.4 ± 9.7 | 110.9 ± 7.6 |
| Clinical Range | 90.0-110.0 | 50.0-65.0 | 100.0-120.0 |
| USASOC (All) | 96.2 ± 10.6 | 61.2 ± 10.3 | 110.9 ± 9.8 |
| 18 Series (3/5 SFG) | 95.7 ± 9.6 | 59.8 ± 10.1 | 111.4 ± 9.1 |
| SWCS (18 Series) | 90.6 ± 12.9 | 62.8 ± 9.8 | 112.6 ± 6.9 |
| Q-Course | 100.7 ± 10.9 | 61.6 ± 15.5 | 109.1 ± 6.5 |
| Pre Q-Course | 97.7 ± 13.1 | 66.6 ± 9.5 | 111.8 ± 19.5 |
| Support | 97.5 ± 10.5 | 62.6 ± 8.2 | 109.5 ± 7.1 |
| Other | 96.9 ± 10.8 | 60.7 ± 11.0 | 110.0 ± 8.2 |

***Internal and External Rotation: Non-dominant arm of professional baseball position players (Brown, 1988). Posterior Shoulder Tightness: Male collegiate swimmers (Oyama, 2006).**

Compared to the clinical range, 8.8-40% of USASOC personnel demonstrated suboptimal motion for shoulder external rotation, 2.9-44.4% for shoulder internal rotation, and 5.4-22.2% for posterior shoulder tightness.

## Hip Extension Flexibility

**Testing Methodology:**
Saunders Digital Inclinometer (The Saunders Group, Chaska, MN)
3 measures
Passive hip extension
Average of 3 joint angles (°)

**Purpose:** Examine hip extension flexibility

**Background:** Hip musculature flexibility is essential for the mobility and generation of force necessary to perform all physical tasks involving the lower extremity. Flexibility deficits at the hip will negatively impact overall performance, contributing to altered kinematics and increased stresses on distal joints leading to acute and chronic injuries that threaten the stability of the lower extremity.

**Data and Results:**

| | Right Extension (degrees) | Left Extension (degrees) |
|---|---|---|
| Top 10th %tile 3SFG | 30.8 | 30.0 |
| Top 25th %tile 3SFG | 26.5 | 25.9 |
| 50th %tile 3SFG | 23.0 | 23.0 |
| Bottom 25th %tile 3SFG | 20.0 | 20.2 |
| Triathletes | 21.0 ± 8.5 | 20.7 ± 6.3 |
| Normative | 17.4 ± 5.9 | 17.4 ± 5.9 |
| Clinical Range | 20.0-40.0 | 20.0-40.0 |
| USASOC (All) | 23.0 ± 4.5 | 23.3 ± 4.4 |
| 18 Series (3/5 SFG) | 23.7 ± 4.7 | 23.8 ± 4.5 |
| SWCS (18 Series) | 22.3 ± 4.4 | 22.9 ± 3.2 |
| Q-Course | 22.7 ± 2.1 | 22.7 ± 2.6 |
| Support | 22.3 ± 4.1 | 22.4 ± 4.4 |
| Other | 21.6 ± 4.4 | 23.1 ± 4.9 |

***Healthy General Population, males 20-44 years old (Soucie, 2011).**

Compared to the clinical range, 7.1-34.5% of USASOC personnel demonstrated suboptimal motion for hip extension.

## Knee Hamstring Flexibility

**Testing Methodology:**
Saunders Digital Inclinometer (The Saunders Group, Chaska, MN)
3 measures
Active knee hamstring
Average of 3 joint angles (°)

**Purpose:** Examine knee hamstring flexibility

**Background:** Maintenance of appropriate flexibility between the quadriceps and hamstring muscle groups contributes to maximal force generation across the available range of motion while also providing for the dynamic stabilization and stiffness necessary for joint protection during demanding tasks involving the lower extremity. Deficits in flexibility in one or both of these muscle groups may contribute to acute or chronic injuries affecting the proper functioning of the knee and jeopardizing overall joint stability.

**Data and Results:**

| | Right Active Knee Extension (degrees) | Left Active Knee Extension (degrees) |
|---|---|---|
| Top 10th %tile 3SFG | 3.7 | 7.3 |
| Top 25th %tile 3SFG | 10.2 | 13.0 |
| 50th %tile 3SFG | 18.3 | 18.7 |
| Bottom 25th %tile 3SFG | 24.3 | 25.0 |
| Athlete* | 34.2 ± 11.9 | 34.2 ± 11.9 |
| Triathletes | 14.5 ± 11.4 | 14.4 ± 9.6 |
| Clinical Range | 0-10.0 | 0-10.0 |
| USASOC (All) | 17.3 ± 10.1 | 19.0 ± 9.7 |
| 18 Series (3/5 SFG) | 17.7 ± 9.8 | 19.0 ± 8.9 |
| SWCS (18 Series) | 16.6 ± 9.5 | 21.3 ± 7.8 |
| Q-Course | 10.6 ± 9.4 | 12.1 ± 8.2 |
| Pre Q-Course | 20.9 ± 12.3 | 22.4 ± 13.2 |
| Support | 15.8 ± 10.3 | 16.8 ± 9.2 |
| Other | 17.2 ± 9.3 | 19.9 ± 10.3 |

Compared to the clinical range, 44.4-85.7% of USASOC personnel demonstrated suboptimal motion for active knee extension.

## Calf Flexibility

**Testing Methodology:**
Saunders Digital Inclinometer (The Saunders Group, Chaska, MN)
3 measures
Active ankle dorsiflexion
Average of 3 joint angles (°)

**Purpose:** Examine ankle dorsiflexion flexibility

**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 will have a negative impact on overall physical performance and may contribute to acute and/or chronic injuries involving the knee and ankle.

**Data and Results:**

| | Right Dorsiflexion (degrees) | Left Dorsiflexion (degrees) |
|---|---|---|
| Top 10th %tile 3SFG | 19.3 | 20.0 |
| Top 25th %tile 3SFG | 17.0 | 17.0 |
| 50th %tile 3SFG | 13.3 | 14.0 |
| Bottom 25th %tile 3SFG | 10.7 | 11.7 |
| Clinical Range | 10.0-25.0 | 10.0-25.0 |
| USASOC (All) | 13.8 ± 3.9 | 14.2 ± 4.1 |
| 18 Series (3/5 SFG) | 13.6 ± 4.1 | 14.0 ± 4.3 |
| SWCS (18 Series) | 15.8 ± 4.2 | 16.5 ± 4.1 |
| Q-Course | 12.9 ± 2.1 | 13.6 ± 2.9 |
| Pre Q-Course | 11.7 ± 4.0 | 12.2 ± 4.1 |
| Support | 14.6 ± 3.3 | 15.0 ± 3.3 |
| Other | 14.3 ± 3.6 | 14.6 ± 3.8 |

Compared to the clinical range, 7.1-35.0% of USASOC personnel demonstrated suboptimal motion for ankle dorsiflexion.

## Posture

**Testing Methodology:**
Modified 40cm combination square (Swanson)
Standing forward shoulder posture and supine pectoralis minor length

Average of 3 measurements (cm)

**Purpose:** Examine shoulder girdle posture and pectoralis minor length

**Background:** Proper shoulder-neck-head postural alignment is important for the performance of rapid, coordinated head-on-neck and all upper limb movements. Appropriate postural alignment is critical for ensuring loads are evenly distributed over the upper body's joint surfaces and within the upper body's variety of tissues. Abnormal postural alignment may result in stress focus points within the joints and/or tissues which could lead to overuse injury or pain and may cause nerves and blood vessels to become trapped as they run from the neck down the arm.

**Data and Results:**

**FORWARD SHOULDER**

| | Right Forward Shoulder (cm) | Left Forward Shoulder (cm) |
|---|---|---|
| Top 10th %tile 3SFG | 14.0 | 14.1 |
| Top 25th %tile 3SFG | 15.2 | 15.2 |
| 50th %tile 3SFG | 16.3 | 16.4 |
| Bottom 25th %tile 3SFG | 17.8 | 17.8 |
| Athlete* | 14.5 ± 2.1 | 14.5 ± 2.1 |
| USASOC (All) | 16.4 ± 1.9 | 16.5 ± 1.9 |
| 18 Series (3/5 SFG) | 16.4 ± 1.9 | 16.5 ± 1.9 |
| SWCS (18 Series) | 16.2 ± 2.2 | 16.4 ± 1.9 |
| Q-Course | 15.9 ± 1.5 | 15.9 ± 1.7 |
| Support | 16.0 ± 1.8 | 16.1 ± 1.6 |
| Other | 17.1 ± 1.9 | 17.1 ± 2.1 |

***Forward Shoulder: Male collegiate swimmers, dominant=right and non-dominant=left (Oyama, 2006).**

Compared to the clinical range, 12.5-66.7% of USASOC personnel demonstrated suboptimal alignment for forward shoulder posture.

**PECTORALIS MINOR**

| | Right Pectoralis Minor (cm) | Left Pectoralis Minor (cm) |
|---|---|---|
| Top 10th %tile 3SFG | 5.5 | 5.6 |
| Top 25th %tile 3SFG | 6.4 | 6.8 |
| 50th %tile 3SFG | 7.6 | 7.6 |
| Bottom 25th %tile 3SFG | 8.3 | 8.3 |
| Normative | 6.3 ± 1.4 | 6.3 ± 1.4 |
| USASOC (All) | 7.6 ± 1.1 | 7.7 ± 1.1 |
| 18 Series (3/5 SFG) | 7.4 ± 1.2 | 7.5 ± 1.2 |
| SWCS (18 Series) | 7.9 ± 0.7 | 8.1 ± 0.8 |
| Q-Course | 7.5 ± 1.2 | 7.3 ± 1.3 |
| Support | 7.8 ± 0.7 | 8.0 ± 0.8 |
| Other | 7.9 ± 1.1 | 8.1 ± 1.1 |

***Pectoralis Minor: Healthy General Population, dominant=right and non-dominant=left (Lewis, 2007).**

Compared to the normative threshold, 72.9-100.0-% of USASOC personnel demonstrated insufficient pectoralis minor length.

**Balance**
**Dynamic Postural Stability**

**Testing Methodology:**
Kistler force plate
Average of 3 trials

**Purpose:** Examine dynamic postural stability through single-leg jump landing

**Background:** The dynamic postural stability index (DPSI) was used to quantify dynamic postural stability. The DPSI provides stability indices for the medial-lateral (MLSI), anterior-posterior (APSI), and vertical (VSI) direction as well as a composite score (DPSI). Lower scores indicate better dynamic postural stability. Accurate sensory information, as measured through single-leg jump landing testing, is essential to the performance of complex motor patterns, maintaining dynamic joint stability, and preventing injury. Deficits in this area may indicate a greater risk for knee, ankle, and lower limb injury.

**RIGHT**

| | MLSI | APSI | VSI | DPSI |
|---|---|---|---|---|
| Top 10th %tile 3SFG | 0.0230 | 0.1178 | 0.2756 | 0.3075 |
| Top 25th %tile 3SFG | 0.0265 | 0.1240 | 0.3100 | 0.3423 |
| 50th %tile 3SFG | 0.0307 | 0.1321 | 0.3383 | 0.3659 |
| Bottom 25th %tile 3SFG | 0.0339 | 0.1417 | 0.3587 | 0.3861 |
| Athlete* | 0.0300 | 0.1400 | 0.3939 | 0.3500 |
| USASOC (All) | 0.0314 ± 0.0068 | 0.1308 ± 0.0116 | 0.3335 ± 0.0432 | 0.3644 ± 0.0392 |
| 18 Series (3/5 SFG) | 0.0303 ± 0.0056 | 0.1330 ± 0.0126 | 0.3368 ± 0.0472 | 0.3640 ± 0.0429 |
| SWCS (18 Series) | 0.0378 ± -- | 0.1273 ± 0.0107 | 0.3214 ± 0.0372 | 0.4145 ± -- |
| Q-Course | 0.0325 ± 0.0059 | 0.1308 ± 0.0081 | 0.3390 ± 0.0230 | 0.3600 ± 0.0037 |
| Pre Q-Course | 0.0320 ± 0.0093 | 0.1307 ± 0.0093 | 0.3349 ± 0.0349 | 0.3614 ± 0.0337 |
| Support | 0.0331 ± 0.0066 | 0.1282 ± 0.0128 | 0.3304 ± 0.0458 | 0.3663 ± 0.0336 |
| Other | 0.0337 ± 0.0085 | 0.1289 ± 0.0086 | 0.3300 ± 0.0401 | 0.3642 ± 0.0397 |

**LEFT**

| | MLSI | APSI | VSI | DPSI |
|---|---|---|---|---|
| Top 10th %tile 3SFG | 0.0220 | 0.1191 | 0.2714 | 0.2991 |
| Top 25th %tile 3SFG | 0.0240 | 0.1242 | 0.2996 | 0.3282 |
| 50th %tile 3SFG | 0.0280 | 0.1327 | 0.3251 | 0.3521 |
| Bottom 25th %tile 3SFG | 0.0320 | 0.1380 | 0.3537 | 0.3821 |
| USASOC (All) | 0.0295 ± 0.0064 | 0.1294 ± 0.0109 | 0.3277 ± 0.0424 | 0.3541 ± 0.0409 |
| 18 Series (3/5 SFG) | 0.0287 ± 0.0060 | 0.1316 ± 0.0099 | 0.3277 ± 0.0460 | 0.3549 ± 0.0438 |
| SWCS (18 Series) | 0.0285 ± 0.0058 | 0.1252 ± 0.0130 | 0.3114 ± 0.0324 | 0.3374 ± 0.0300 |
| Q-Course | 0.0304 ± 0.0054 | 0.1308 ± 0.0085 | 0.3434 ± 0.0221 | 0.3690 ± 0.0208 |
| Pre Q-Course | 0.0324 ± 0.0110 | 0.1310 ± 0.0075 | 0.3355 ± 0.0330 | 0.3622 ± 0.0307 |
| Support | 0.0298 ± 0.0056 | 0.1271 ± 0.0134 | 0.3318 ± 0.0454 | 0.3569 ± 0.0453 |
| Other | 0.0304 ± 0.0055 | 0.1265 ± 0.0111 | 0.3212 ± 0.0404 | 0.3470 ± 0.0392 |

***Recreational active males (Pederson, 2011).**

Compared to the normative threshold, 23.1-35.5% of USASOC personnel demonstrated suboptimal performance for medial/lateral postural stability, 1.1-2.7% for anterior/posterior postural stability, 17.6-20.5% for vertical postural stability, and 19.2-22.6% dynamic postural stability. Bilateral asymmetry for postural stability was identified in 56.0% of USASOC personnel for medial/lateral, 9.9% for anterior/posterior, 26.9% for vertical, and 18.7% for dynamic.

## Biomechanics
## Scapular Kinematics: Humeral Elevation and Depression in the Scapular Plane

**Testing Methodology:**
3D optical capture system (Vicon, Centennial, CO)

**Purpose:** Examine scapular kinematics with respect to the thorax

**Background:** Abnormal scapular kinematics, such as decreased scapular lateral rotation, is theorized to be related to shoulder injuries and pathologies such as subacromial impingement, as well as decreased athletic performance. Such altered scapular kinematics has been identified in athletes involved in overhead throwing or rock climbing, as well as patients with shoulder impingement injury. Overhead tasks such as reaching, loading of boats, climbing, and swimming are commonly performed by an Operator in military training and missions, and normal scapular kinematics are a critical component for Operators to perform such tasks while minimizing the risk of injury.

**Data and Results:**

**RIGHT HUMERAL ELEVATION**

| | 90 Degrees | | | 120 Degrees | | |
|---|---|---|---|---|---|---|
| | IR( +)/ER (-) | UR (+)/DR (-) | AT(-)/PT (+) | IR( +)/ER (-) | UR (+)/DR (-) | AT(-)/PT (+) |
| Top 10th %tile 3SFG | 20.4 | 33.2 | -0.7 | 18.5 | 43.6 | 8.3 |
| Top 25th %tile 3SFG | 24.2 | 28.4 | -4.3 | 24.7 | 36.8 | 3.5 |
| 50th %tile 3SFG | 30.1 | 25.1 | -9.2 | 33.7 | 32.9 | -1.3 |
| Bottom 25th %tile 3SFG | 35.4 | 18.6 | -12.9 | 41.3 | 25.6 | -6.7 |
| Normative* | 36.8 ± 10.9 | 18.0 ± 9.4 | -4.2 ± 6.3 | 39.0 ± 12.8 | 24.9 ± 9.4 | 3.2 ± 9.7 |
| Athlete* | 43.5 | -- | -9.9 | 47.5 | 40.7 | -8.1 |
| USASOC (All) | 29.5 ± 8.7 | 15.8 ± 4.6 | -4.8 ± 4.9 | 34.6 ± 10.5 | 21.4 ± 6.4 | 1.1 ± 5.3 |
| 18 Series (3/5 SFG) | 30.1 ± 7.0 | 24.4 ± 6.7 | -8.4 ± 5.9 | 33.2 ± 10.2 | 32.6 ± 7.9 | -1.6 ± 7.0 |
| SWCS (18 Series) | 27.1 ± 6.4 | 28.6 ± 6.2 | -7.7 ± 3.9 | 28.1 ± 9.4 | 37.1 ± 6.7 | -0.1 ± 5.7 |
| Q-Course | 26.9 ± 5.9 | 27.5 ± 6.6 | -8.2 ± 4.0 | 28.0 ± 8.7 | 36.1 ± 7.0 | -0.8 ± 5.5 |
| Support | 28.7 ± 7.0 | 29.1 ± 4.5 | -8.7 ± 5.3 | 29.8 ± 7.5 | 38.1 ± 5.6 | -3.2 ± 6.1 |
| Other | 32.0 ± 6.2 | 28.0 ± 5.1 | -9.9 ± 6.5 | 35.3 ± 8.2 | 37.0 ± 5.7 | -4.4 ± 8.2 |

**LEFT HUMERAL ELEVATION**

| | 90 Degrees | | | 120 Degrees | | |
|---|---|---|---|---|---|---|
| | IR( +)/ER (-) | UR (+)/DR (-) | AT(-)/PT (+) | IR( +)/ER (-) | UR (+)/DR (-) | AT(-)/PT (+) |
| Top 10th %tile 3SFG | 20.8 | 33.0 | 2.0 | 16.9 | 40.9 | 9.4 |
| Top 25th %tile 3SFG | 24.2 | 28.8 | -3.1 | 23.6 | 37.1 | 4.2 |
| 50th %tile 3SFG | 29.6 | 24.1 | -7.8 | 30.6 | 31.9 | -1.1 |
| Bottom 25th %tile 3SFG | 34.7 | 18.8 | -12.4 | 37.3 | 26.4 | -5.3 |
| Normative* | 36.8 ± 10.9 | 18.0 ± 9.4 | -4.2 ± 6.3 | 39.0 ± 12.8 | 24.9 ± 9.4 | 3.2 ± 9.7 |
| Athlete* | 43.5 | -- | -9.9 | 47.5 | 40.7 | -8.1 |
| USASOC (All) | 30.0 ± 7.5 | 25.0 ± 5.7 | -8.0 ± 5.8 | 30.2 ± 9.4 | 33.2 ± 6.4 | -1.2 ± 7.0 |
| 18 Series (3/5 SFG) | 29.6 ± 7.2 | 23.9 ± 6.3 | -7.3 ± 8.2 | 30.6 ± 9.8 | 31.9 ± 6.9 | -0.8 ± 7.1 |
| SWCS (18 Series) | 29.7 ± 6.6 | 26.6 ± 3.7 | -7.3 ± 3.0 | 29.3 ± 6.8 | 35.2 ± 5.3 | 1.0 ± 3.9 |
| Q-Course | 30.5 ± 7.0 | 24.8 ± 4.6 | -10.0 ± 4.7 | 28.8 ± 8.0 | 33.1 ± 8.0 | -1.1 ± 5.8 |
| Support | 29.4 ± 8.0 | 26.4 ± 4.8 | -7.7 ± 4.9 | 27.9 ± 8.4 | 34.5 ± 5.1 | -0.0 ± 5.9 |
| Other | 31.5 ± 8.8 | 26.8 ± 4.5 | -9.2 ± 7.1 | 32.7 ± 10.6 | 35.6 ± 5.2 | -4.1 ± 5.6 |

**RIGHT HUMERAL DEPRESSION**

| | 90 Degrees | | | 120 Degrees | | |
|---|---|---|---|---|---|---|
| | IR( +)/ER (-) | UR (+)/DR (-) | AT(-)/PT (+) | IR( +)/ER (-) | UR (+)/DR (-) | AT(-)/PT (+) |
| Top 10th %tile 3SFG | 18.8 | 33.4 | 1.8 | 16.8 | 44.5 | 8.4 |
| Top 25th %tile 3SFG | 23.2 | 29.8 | -1.9 | 25.2 | 37.4 | 5.1 |
| 50th %tile 3SFG | 31.0 | 25.6 | -6.5 | 34.7 | 33.0 | -1.1 |
| Bottom 25th %tile 3SFG | 36.2 | 19.7 | -10.7 | 43.0 | 26.4 | -5.0 |
| Normative* | 36.8 ± 10.9 | 18.0 ± 9.4 | -4.2 ± 6.3 | 39.0 ± 12.8 | 24.9 ± 9.4 | 3.2 ± 9.7 |
| Athlete* | 44.0 | - | -7.3 | 46.0 | -39.2 | -5.3 |
| USASOC( All) | 29.2 ± 7.5 | 26.6 ± 6.8 | -7.0 ± 6.2 | 32.4 ± 10.2 | 34.5 ± 7.6 | -1.1 ± 7.3 |
| 18 Series (3/5 SFG) | 29.5 ± 7.8 | 25.1 ± 7.0 | -6.4 ± 6.1 | 33.6 ± 11.1 | 32.6 ± 8.0 | -0.4 ± 7.0 |
| SWCS (18 Series) | 26.5 ± 7.4 | 29.5 ± 5.8 | -5.9 ± 4.3 | 27.8 ± 8.6 | 37.6 ± 6.5 | 1.1 ± 5.2 |
| Q-Course | 28.4 ± 7.1 | 25.4 ± 6.3 | -6.8 ± 6.7 | 30.7 ± 8.9 | 33.1 ± 6.1 | -0.5 ± 7.4 |
| Support | 28.2 ± 7.1 | 29.7 ± 5.7 | -7.5 ± 5.4 | 29.8 ± 7.8 | 38.0 ± 6.2 | -1.9 ± 3.4 |
| Other | 31.1 ± 6.2 | 27.9 ± 6.4 | -8.3 ± 7.5 | 34.6 ± 9.1 | 37.2 ± 5.7 | -3.3 ± 9.0 |

**LEFT HUMERAL DEPRESSION**

| | 90 Degrees | | | 120 Degrees | | |
|---|---|---|---|---|---|---|
| | IR( +)/ER (-) | UR (+)/DR (-) | AT(-)/PT (+) | IR( +)/ER (-) | UR (+)/DR (-) | AT(-)/PT (+) |
| Top 10th %tile 3SFG | 18.9 | 32.0 | 2.9 | 16.1 | 41.2 | 9.2 |
| Top 25th %tile 3SFG | 22.9 | 29.6 | -1.3 | 23.8 | 36.8 | 5.9 |
| 50th %tile 3SFG | 27.8 | 24.7 | -6.5 | 30.0 | 31.6 | -0.1 |
| Bottom 25th %tile 3SFG | 33.1 | 19.4 | -10.2 | 36.6 | 26.7 | -4.4 |
| Normative* | 36.8 ± 10.9 | 18.0 ± 9.4 | -4.2 ± 6.3 | 39.0 ± 12.8 | 24.9 ± 9.4 | 3.2 ± 9.7 |
| Athlete* | 44.0 | - | -7.3 | 46.0 | -39.2 | -5.3 |
| USASOC( All) | 28.6 ± 7.5 | 25.7 ± 5.8 | -6.4 ± 5.9 | 29.8 ± 9.5 | 33.3 ± 6.6 | 0.1 ± 7.0 |
| 18 Series (3/5 SFG) | 28.0 ± 7.4 | 24.5 ± 6.4 | -5.6 ± 6.1 | 30.3 ± 10.0 | 31.8 ± 7.0 | 0.5 ± 7.2 |
| SWCS (18 Series) | 28.9 ± 7.5 | 27.4 ± 4.1 | -5.8 ± 3.1 | 28.8 ± 7.4 | 35.6 ± 5.0 | 1.9 ± 4.0 |
| Q-Course | 29.2 ± 7.3 | 25.6 ± 5.6 | -8.1 ± 4.8 | 28.6 ± 7.5 | 33.3 ± 6.4 | 0.9 ± 7.0 |
| Support | 28.2 ± 7.5 | 27.1 ± 3.8 | -6.0 ± 5.2 | 27.3 ± 8.5 | 34.3 ± 5.2 | 1.7 ± 5.7 |
| Other | 30.0 ± 8.2 | 27.5 ± 5.1 | -7.8 ± 7.3 | 32.3 ± 10.2 | 36.2 ± 5.5 | -3.0 ± 8.2 |

***Right Elevation & Depression: Male construction workers (Borstad, 2002). Normative Population: Healthy & physically active males (Myers, 2005)**

Because the scapula serves as the foundation for shoulder motion adequate and optimal motion is necessary for overhead tasks to allow for proper alignment of the upper arm which prevents impingement and shoulder injury. In order to maintain optimal alignment during overhead activity it is necessary for the scapula to upwardly rotate, tilt posteriorly and externally rotate. This allows the upper arm to move smoothly and decreases the risk of overuse injuries.

Normal scapular internal rotation is approximately 35-40° during humeral elevation/depression above 90°; increased internal rotation may contribute to potential shoulder injury. The average scapular internal rotation at 90° humeral elevation for 3-5SFG Operators was comparable to all Operator groups (18 Series, SWCS, Q-Course, Support and Other), but was less than both the normative and an athlete groups by up to 9° and 16° respectively. The average scapular internal rotation at 120° humeral elevation for 3-5SFG Operators was comparable to Support and Other groups, up to 6° greater than SWCS, and 5°

greater than Q-Course, but was less than both the normative and an athlete groups by up to 9° and 17° respectively. On average the 3SFG Operators demonstrated favorable scapular internal rotation during overhead humeral elevation.

Normal scapular upward rotation is approximately 18-40° during humeral elevation/depression above 90°; decreased upward rotation may contribute to potential shoulder injury. The average scapular upward rotation at 90° humeral elevation for 3SFG Operators demonstrated less upward rotation compared to all Operator groups by up to 5□, but was 7° greater than the normative group. The average scapular upward rotation at 120° humeral elevation for 3SFG Operators demonstrated less upward rotation compared to all Operator groups by up to 5□, but was up to 9° greater than the normative group and up to 9° less than the athlete group. On average the 3SFG Operators demonstrated favorable scapular upward rotation during overhead humeral elevation.

Normal scapular anterior tilt is approximately -4-3° (anterior tilt is negative) during humeral elevation/depression and moves toward/into posterior tilt as the arm approaches 120° of elevation; increased anterior tilt may contribute to potential shoulder injury. The average scapular anterior tilt at 90° humeral elevation for 3SFG Operators was comparable to all Operators and the athlete group, but was up to 4° more anteriorly tilted compared to the normative population. The average scapular anterior tilt at 120° humeral elevation for 3SFG Operators was comparable to all Operators, but was up to 5° more anteriorly tilted compared to the normative group and up to 7° less anteriorly tilted compared to the athlete group. On average the 3SFG operators demonstrated favorable scapular anterior tilt during humeral elevation.

**Biomechanics**
**Hip Kinematics: Two-Legged Stop-Jump**

**Testing Methodology:**
3D optical capture system (Vicon, Centennial, CO)

**Purpose:**
Examine hip flexion at initial contact

**Background:**
The hip and surrounding musculature 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 subsequent absorption of joint forces.

**Data and Results:**

**RIGHT**

| | Hip Flexion @ Initial Contact (degrees) | Hip Abduction @ Initial Contact (degrees) |
|---|---|---|
| Top 10th %tile 3SFG | 55.6 | 5 to -5 |
| Top 25th %tile 3SFG | 49.7 | 10 to -10 |
| 50th %tile 3SFG | 42.1 | 15 to -15 |
| Bottom 25th %tile 3SFG | 36.9 | 20 to -20 |
| Clinical Value | -- | 0.0 |
| Triathletes | 51.1 ± 13.2 | -2.6 ± 3.5 |
| USASOC (All) | 42.1 ± 9.3 | -3.2 ± 3.4 |
| 18 Series (3/5 SFG) | 43.2 ± 9.2 | -3.7 ± 3.5 |
| SWCS (18 Series) | 38.6 ± 6.8 | -2.2 ± 2.9 |
| Q-Course | 47.2 ± 7.7 | -3.6 ± 2.0 |
| Support | 41.3 ± 11.0 | -2.5 ± 4.1 |
| Other | 38.6 ± 7.9 | -2.8 ± 2.8 |

**LEFT**

| | Hip Flexion @ Initial Contact (degrees) | Hip Abduction @ Initial Contact (degrees) |
|---|---|---|
| Top 10th %tile 3SFG | 55.5 | 5 to -5 |
| Top 25th %tile 3SFG | 50.2 | 10 to -10 |
| 50th %tile 3SFG | 43.4 | 15 to -15 |
| Bottom 25th %tile 3SFG | 36.7 | 20 to -20 |
| Clinical Value | -- | 0.0 |
| Triathletes | 54.4 ± 15.4 | -2.0 ± 4.2 |
| USASOC (All) | 43.0 ± 9.7 | -4.4 ± 3.8 |
| 18 Series (3/5 SFG) | 43.9 ± 9.4 | -4.5 ± 3.8 |
| SWCS (18 Series) | 40.3 ± 7.3 | -4.7 ± 3.3 |
| Q-Course | 47.1 ± 8.1 | -6.3 ± 4.5 |
| Support | 42.4 ± 12.1 | -3.6 ± 4.3 |
| Other | 39.9 ± 8.6 | -4.1 ± 3.2 |

The hip flexion position at initial contact was inefficient in 70-74% of personnel. Asymmetry was identified in 25% of personnel. Hip abduction angles at initial contact were within the optimal range of +/- 5 degrees, however 30-42% landed in a suboptimal position. Landing asymmetry was identified in 97% of personnel.

## Knee Kinematics: Two-Legged Stop-Jump

**Testing Methodology:**
3D optical capture system (Vicon, Centennial, CO)

**Purpose:**
Examine maximum knee flexion and knee flexion at initial contact.

**Background:**
Flexing the knee at landing and throughout dynamic tasks is essential to absorbing the dangerous landing forces experienced throughout the lower extremity. Inadequate flexion combined with a valgus knee angle can increase the strain on knee ligaments which can lead to tissue failure and injury.

**Data and Results:**

**RIGHT**

| | Knee Flexion @ Initial Contact (degrees) | Knee Valgus @ Initial Contact (degrees) | Maximum Knee Flexion (degrees) |
|---|---|---|---|
| Top 10th %tile 3SFG | 35.8 | 5 to -5 | 109.2 |
| Top 25th %tile 3SFG | 30.0 | 10 to -10 | 99.6 |
| 50th %tile 3SFG | 24.8 | 15 to -15 | 88.6 |
| Bottom 25th %tile 3SFG | 18.8 | 20 to -20 | 81.7 |
| Clinical Value | -- | 0.0 | -- |
| Triathletes | 29.9 ± 8.7 | 5.6 ± 3.8 | 82.4 ± 11.9 |
| USASOC (All) | 24.2 ± 7.4 | 5.2 ± 5.3 | 91.6 ± 15.2 |
| 18 Series (3/5 SFG) | 24.9 ± 7.6 | 5.5 ± 5.5 | 91.0 ± 15.3 |
| SWCS (18 Series) | 23.0 ± 6.9 | 2.8 ± 5.5 | 96.1 ± 17.5 |
| Q-Course | 26.4 ± 6.4 | 6.6 ± 4.7 | 89.2 ± 19.1 |
| Support | 23.4 ± 6.7 | 5.7 ± 4.7 | 91.4 ± 15.9 |
| Other | 21.9 ± 7.3 | 4.5 ± 5.1 | 93.1 ± 11.9 |

**LEFT**

| | Knee Flexion @ Initial Contact (degrees) | Knee Valgus @ Initial Contact (degrees) | Maximum Knee Flexion (degrees) |
|---|---|---|---|
| Top 10th %tile 3SFG | 34.7 | 5 to -5 | 112.4 |
| Top 25th %tile 3SFG | 29.4 | 10 to -10 | 98.1 |
| 50th %tile 3SFG | 25.0 | 15 to -15 | 87.5 |
| Bottom 25th %tile 3SFG | 20.2 | 20 to -20 | 79.2 |
| Clinical Value | -- | 0.0 | -- |
| Triathletes | 34.8 ± 9.5 | 6.2 ± 9.1 | 84.8 ± 8.3 |
| USASOC (All) | 24.6 ± 7.6 | 5.2 ± 6.9 | 90.2 ± 15.6 |
| 18 Series (3/5 SFG) | 25.0 ± 8.1 | 5.2 ± 7.2 | 89.3 ± 15.6 |
| SWCS (18 Series) | 24.0 ± 6.3 | 3.4 ± 5.2 | 95.0 ± 20.1 |
| Q-Course | 26.8 ± 5.9 | 6.3 ± 5.1 | 88.5 ± 17.7 |
| Support | 24.2 ± 7.1 | 4.7 ± 6.3 | 89.2 ± 17.0 |
| Other | 23.4 ± 7.5 | 6.3 ± 8.1 | 92.7 ± 10.1 |

The knee flexion angle at initial contact was insufficient in 60.9-84.5%. Knee flexion asymmetry was identified in 68.4%. The knee valgus angle at initial contact was outside of the optimal range (0 +/- 5 degrees) with 53.5-54.6% suboptimal. Knee valgus asymmetry was identified in 92%. Maximum knee flexion was suboptimal in 10.3-15.5% with asymmetry identified in 12% of personnel.

**Ground Reaction Forces: Two-Legged Stop-Jump**

**Testing Methodology:**
Kistler force plates (Kistler Corp, Worthington, OH)
Collected at 1200 Hz

**Purpose:**
Examine peak vertical ground reaction forces

**Background:**
Vertical ground reaction forces directly correlate with high joint forces. Individuals who are able to decrease landing forces through modified landing strategies should be able to mitigate these forces and reduce their risk of injury.

**Data and Results:**

**RIGHT**

| | Peak Vertical GRF (%BW) |
|---|---|
| Top 10th %tile 3SFG | 142.4 |
| Top 25th %tile 3SFG | 166.2 |
| 50th %tile 3SFG | 196.2 |
| Bottom 25th %tile 3SFG | 242.0 |
| Triathletes | 210.8 ± 48.1 |
| USASOC (All) | 208.5 ± 69.3 |
| 18 Series (3/5 SFG) | 212.4 ± 72.4 |
| SWCS (18 Series) | 194.5 ± 61.8 |
| Q-Course | 238.2 ± 84.6 |
| Support | 195.8 ± 54.7 |
| Other | 205.1 ± 70.4 |

**LEFT**

| | Peak Vertical GRF (%BW) |
|---|---|
| Top 10th %tile 3SFG | 145.4 |
| Top 25th %tile 3SFG | 165.1 |
| 50th %tile 3SFG | 189.5 |
| Bottom 25th %tile 3SFG | 225.0 |
| Triathletes | 224.3 ± 63.2 |
| USASOC (All) | 194.1 ± 52.5 |
| 18 Series (3/5 SFG) | 201.5 ± 53.0 |
| SWCS (18 Series) | 189.1 ± 61.8 |
| Q-Course | 200.8 ± 67.4 |
| Support | 181.4 ± 45.3 |
| Other | 181.0 ± 45.6 |

Peak ground reaction forces were suboptimal in 29.3% of personnel with asymmetry identified in 67.2%.

**Biomechanics Summary:** USASOC operators tended to land with greater hip and knee extension at initial contact. This strategy may place operators at an increased risk of injury by minimizing the effectiveness of larger muscles to provide dynamic joint stability upon impact. At the same point in landing operators also tended to have increased knee valgus angle which has been associated to the occurrence of knee injury by placing greater strain on ligamentous structures. Conversely USASOC operators also tended to utilize greater knee flexion throughout landing which can help decrease the risk of lower extremity injury by allowing the body to better absorb landing forces. It is likely because of this increased knee flexion that we also saw smaller peak vertical ground reaction forces compared to triathletes. However, the top $10^{th}$ percentile of USASOC shows that better landing mechanics are achievable and they can further decrease landing forces, further lowering the risk of musculoskeletal injury.

**Physiology**

## Body Composition

**Testing Methodology:**
BOD POD body composition tracking system

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

**Background:** Physical performance can be 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 and body fat. Similarly, 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. Low body fat stores may decrease the available fuel to sustain prolonged training and combat missions. Additionally, the varying terrains and environmental conditions further support the importance of optimal body composition distribution. From a long-term health prospective, less body fat will decrease the risk of hypokinetic diseases (i.e., cardiovascular disease, diabetes, hypertension, hypercholesterolemia).

**Data and Results:**

| | Body Fat (%) | Height (inches) | Weight (pounds) |
|---|---|---|---|
| Top 10th %tile 3SFG | 9.1 | -- | -- |
| Top 25th %tile 3SFG | 13.0 | -- | -- |
| 50th %tile 3SFG | 16.8 | -- | -- |
| Bottom 25th %tile 3SFG | 20.4 | -- | -- |
| Athlete* | 15.42 | -- | -- |
| Triathletes | 12.31 ± 4.37 | -- | -- |
| USASOC (All) | 18.46 ± 6.86 | 70.50 ± 2.68 | 188.68 ± 25.89 |
| 18 Series (3/5 SFG) | 16.64 ± 5.59 | 70.50 ± 2.31 | 187.79 ± 23.63 |
| SWCS (18 Series) | 21.74 ± 5.85 | 70.99 ± 2.39 | 190.19 ± 24.69 |
| Q-Course | 12.52 ± 3.40 | 72.13 ± 2.30 | 184.97 ± 23.09 |
| Pre Q-Course | 17.15 ± 4.89 | 69.20 ± 4.70 | 177.91 ± 39.75 |
| Support | 20.70 ± 7.59 | 70.02 ± 2.62 | 191.12 ± 23.96 |
| Other | 22.90 ± 8.31 | 70.13 ± 2.24 | 193.30 ± 26.36 |

***NMRL Database of Professional Football Players**

Ideal body composition for SOF to optimize physical and tactical readiness remains unknown. Complicated by environmental conditions and tactical requirements. Excessive body fat diminishes physical readiness and performance. Based on previous body composition and injury data collected on SOF, 15% body fat was identified as a threshold of marked increase in musculoskeletal injuries. At this established threshold, 22.2-85.7% of USASOC personnel were above 15% body fat.

## Anaerobic Power/Anaerobic Capacity

**Testing Methodology:**
Velotron cycling ergometer (RacerMate, Inc., Seattle, WA)

**Purpose:** Examine 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, along with other diminished physiological characteristics, as a result of non-scientifically structured training have been directly related to an increased risk of injury and impaired performance. Anaerobic power/anaerobic capacity is critical when high intensity, high stress bouts are followed by the need for tactical performance (e.g., gun firing).

**Data and Results:**

| | Anaerobic Power (W/kg) | Anaerobic Capacity (W/kg) |
|---|---|---|
| Top 10th %tile 3SFG | 16.0 | 9.2 |
| Top 25th %tile 3SFG | 14.9 | 9.0 |
| 50th %tile 3SFG | 13.9 | 8.5 |
| Bottom 25th %tile 3SFG | 12.9 | 7.9 |
| Athlete* | 16.86 ± 1.35 | 10.45 ± 0.56 |
| Triathletes | 13.75 ± 1.05 | 9.25 ± 0.70 |
| USASOC (All) | 13.86 ± 1.35 | 8.06 ± 1.10 |
| 18 Series (3/5 SFG) | 13.93 ± 1.44 | 8.35 ± 0.90 |
| SWCS (18 Series) | 14.16 ± 1.37 | 7.64 ± 1.13 |
| Q-Course | 14.64 ± 0.85 | 8.56 ± 0.90 |
| Pre Q-Course | 13.74 ± 1.09 | 8.33 ± 0.87 |
| Support | 13.70 ± 1.40 | 7.55 ± 1.26 |
| Other | 13.57 ± 1.15 | 7.51 ± 1.23 |

***NMRL Database of Professional Ice Hockey Players**

Compared to the athlete model threshold, 55.6-94.4% of USASOC personnel were suboptimal for anaerobic power and 88.9-100% were suboptimal for anaerobic capacity. Anaerobic capacity demonstrated a negative relationship with body composition (r = -0.62).

## Aerobic Capacity

**Testing Methodology:**
Viasys Oxycon Mobile portable ergospirometry system
Arkray LactatePro blood lactate test meter

**Purpose:**
Examine aerobic capacity ($VO_{2max}$/lactate threshold)

**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 Operators and increased injuries as compared to Operators 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 Operator more fatigue resistant.

**Data and Results:**

**VO2**

| | VO2 max (ml/kg/min) | VO2 @ LT (ml/kg/min) | VO2 @ LT (% VO2 max) |
|---|---|---|---|
| Top 10th %tile 3SFG | 55.6 | 46.1 | 89.8 |
| Top 25th %tile 3SFG | 51.6 | 40.5 | 86.1 |
| 50th %tile 3SFG | 47.3 | 34.8 | 75.1 |
| Bottom 25th %tile 3SFG | 44.1 | 32.3 | 70.3 |
| Triathletes | 69.76 ± 7.29 | 58.20 ± 7.30 | 83.66 ± 8.52 |
| USASOC (All) | 46.97 ± 5.66 | 36.60 ± 5.99 | 78.09 ± 9.47 |
| 18 Series (3/5 SFG) | 47.79 ± 5.10 | 36.73 ± 5.99 | 77.18 ± 9.33 |
| SWCS (18 Series) | 46.91 ± 5.57 | 37.69 ± 6.76 | 80.90 ± 10.82 |
| Q-Course | 51.29 ± 3.08 | 40.22 ± 4.20 | 78.68 ± 10.32 |
| Pre Q-Course | 48.58 ± 3.38 | 36.74 ± 4.88 | 75.21 ± 9.00 |
| Support | 45.65 ± 6.31 | 35.38 ± 7.02 | 77.57 ± 9.27 |
| Other | 43.75 ± 6.62 | 36.28 ± 5.42 | 82.13 ± 9.06 |

Compared to the athlete model, 100% of USASOC personnel were below threshold for aerobic capacity and 50-82.3% were suboptimal for lactate threshold. Aerobic capacity demonstrated a negative relationship with body composition (r = -0.67).

**Personnel**
COL Shawn Kane, MD, Deputy Command Surgeon briefed on project and will be named USASOC PI to replace COL Pete Benson. LTC Jeff Morgan, MD, Director THOR3 will remain a collaborator on project. Amanda Rawl, MS, resigned her position to assume a role with THOR3, which will assist with continued research implementation. Jim Bakey, MS hired to fill open position at Human Performance Research Laboratory. Julie Kresta, PhD was on a 12 week maternity leave and has since resumed her laboratory duties.

**Human Subject Protections**
Human subject protections are maintained by review boards from the University of Pittsburgh, Womack Army Medical Center, and higher level review performed by Clinical Investigation Regulatory Office and Office of Research Protections, Human Research Protection Office.

***University of Pittsburgh***
Annual renewal was submitted to the University of Pittsburgh and was approved September 3, 2013. The next expiration is September 2, 2014 (approval letter Appendix 3).

***Womack Army Medical Center***
Continuing review was submitted to Womack Army Medical Center and was approved April 12, 2013. The next expiration is April 11, 2014. (approval letter Appendix 3).

**Reportable Outcomes**
**Abstracts**
Abt J, Sell T, Lovalekar M, Bozich A, Benson P, Morgan J, Lephart S. Injury Epidemiology of US Army Special Operations Forces. Targeted Conference- American College of Sports Medicine (In Review).

**Manuscripts**
Abt J, Sell T, Lovalekar M, Bozich A, Benson P, Morgan J, Lephart S. Injury Epidemiology of US Army Special Operations Forces. Draft complete and in review with co-investigators. Targeted Journal- Military Medicine.

**Grant Submissions**
Abt J, Sell T, Nagai T, Smalley B, Lephart S. Modifiable and Non-Modifiable Risk Factors of Neck and Low Back Pain in Army Helicopter Aviators. Submitted to US Army Medical Research and Materiel Command, Military Medical Research and Development, W81XWH-13-MOMJPC5-IPPEHA.

Abt J, Sell T, Allison K, Beals K, Nagle E, Lephart S. Prediction of Aquatic-Based Performance in Naval Special Warfare Operators. Submitted to Air Force Office of Scientific Research, Defense University Research Instrumentation Program, PA-AFOSR-2013-0001.

Abt J, Sell T, Beals K, Benson P, Morgan J, Lephart S. USASOC Injury Prevention/Performance Optimization Musculoskeletal Screening Initiative. Submitted to US Army Medical Research and Materiel Command, Military Medical Research and Development, W81XWH-09-DMRDP-ARATDA (Cost Extension- Phase 4).

**Conclusions**
Not applicable

**References**
Not applicable

**Appendices**
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# Injury Epidemiology of US Army Special Operations Forces

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**Introduction**

Despite significant study of injury epidemiology in US military personnel,[1-5] limited published data have described such injury patterns of US Special Operations Forces (SOF).[6-9] Anecdotal evidence provided by medical, human performance, and training leadership suggests musculoskeletal injuries continue to be a readiness impediment to SOF, including US Army Special Operations Command (USASOC). The advanced tactical and physical requirements of USASOC, and fiscal implications, including direct medical costs and manpower, of training USASOC, highlight the importance of mitigating those musculoskeletal injuries with the potential to be preventable. Thus, it is critical to assess the extent of musculoskeletal injuries in this specialized community by describing injury epidemiology.

Musculoskeletal injuries in SOF have been previously identified in various SOF cohorts, and these injuries have a negative impact on force readiness.[6-9] Naval Special Warfare (NSW) personnel sustained 0.9 to 3.2 injuries per 100 personnel per month (approximately 11 to 38 injuries per 100 personnel per year).[8] Of these injuries, 21% of the diagnoses were progressed to surgery and associated loss of time due to surgery and rehabilitation.[8] Similarly, of 87 Marine Corps Special Operations personnel surveyed, 28 sustained at least one injury during a pre-deployment training cycle of approximately 12 months, resulting in 41 total injuries (approximately 47 injuries per 100 personnel per year).[7] Of those injured, over 80% reported that their ability to train was hindered as a result of their injury. Although a similar statistic on injury frequency and severity is not available in USASOC operators, based on all diagnoses encountered by US Army 5th Special Force Group in the Armed Forces Health Longitudinal Technology Application (AHLTA) database, after "administrative" categories were excluded, roughly 40% of all diagnoses are related to musculoskeletal injuries.[6] Those musculoskeletal injuries commonly involve back/neck, knee, shoulder, and ankle. Given the significance of musculoskeletal injuries sustained in SOF, further research is warranted to investigate injury frequency and severity in USASOC personnel in order to facilitate development of appropriate injury prevention training programs.

Consistent with the public health approach to injury prevention and control,[10] University of Pittsburgh human performance and injury prevention research with USASOC was initiated to support development of USASOC's Tactical Human Optimization, Rapid Rehabilitation, and Reconditioning (THOR3) program. The first phase of the initiative is to collect injury data from the target population to understand the magnitude, nature, and impact of the injury problem.[2] Injury data, such as types of injuries, locations, and activities/mechanisms of injuries when injury occurred, would play an essential tool for clinicians and operators to understand injury epidemiology in their community. Further, due to limitations of automated database (AHLTA) and categories of injury diagnoses using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM), intricate information such as activities and mechanisms of injuries when injuries occurred have not been well examined in USASOC community. Therefore, the purpose of this initial analysis was to describe the injury epidemiology of the 3rd Special Operations Forces Group utilizing self-reported injury histories. Clinically, injury epidemiology could assist subsequent research phases in the model[2] and ultimately identify the priorities necessary for refinement in their current physical training program to reduce musculoskeletal injuries and enhance force readiness.

**Methods**

Human subject protections approvals were obtained by the Institutional Review Boards of the University of Pittsburgh and Womack Army Medical Center. Musculoskeletal injury data were captured from individual Operator self-reports obtained as a part of a comprehensive biomechanical, musculoskeletal, physiological, and nutritional laboratory test protocol.

Self-reported musculoskeletal injury data were collected on 106 male USASOC Operators (Age: 31.7 ± 5.3 years, Height: 179.0 ± 5.5 cm, Mass: 85.9 ± 10.9 kg, Years of experience: 11.0 ± 5.5 years), from 3rd Special Forces Group (3SFG). Subjects were included in the University of Pittsburgh human performance and injury prevention research with USASOC if they were aged 18-60 years (inclusive); had no recent (3 month) history of TBI, other neurological, or balance disorder; had no recent (3 month) history of upper/lower extremity or back musculoskeletal injury; had no history of metabolic, cardiovascular, or pulmonary disorder; and, were cleared for full and unrestricted duty.

Injury data were entered using a customized online application into a database, the University of Pittsburgh Military Epidemiology Database (UPitt-MED), by clinically-trained research associates to ensure an accurate and thorough injury history. The UPitt-MED questionnaires included questions about injury anatomic location, anatomic sub-location, injury type, activity during which injury occurred, cause of injury, mode of onset of injury, mechanism of injury, and treatment received.

For the purposes of this analysis, an unintentional musculoskeletal injury was defined as an injury to the musculoskeletal system (bones, ligaments, muscles, tendons, etc.) that, if occurring after enlistment, resulted in alteration in tactical activities, tactical training, or physical training for a minimum of one day, regardless if medical attention was sought. If the injury occurred prior to enlistment, then the injury resulted in alteration in activities of daily living and/or training/athletic activities for greater than one day, regardless if medical attention was sought. This includes conditions such as sprains, strains, and fractures (broken bones), but not contusions or lacerations (bruises and cuts). In addition to unintentional musculoskeletal injuries, conditions such as concussions and heat-related illnesses are of interest.

Injuries were then further classified as preventable or not preventable. Preventable injuries are those considered to be able to be reduced through injury prevention programs, while may be preventable injuries are potentially preventable through injury prevention programs, but not enough information is present to definitively classify them as preventable. Not preventable injuries are those not able to be deterred through injury prevention programs, such as those sustained during motor vehicle accidents, direct contact, or stepping in a ditch. Other not preventable injuries include certain fracture, such as to the face, fingers, or toes.

***Statistical Analysis***

Self-reported injury data during a period of one year prior to the date of laboratory testing have been included in the injury description. Injuries were described using relative frequency (percent). The frequency of injuries was calculated as the number of injuries per 100 subjects per year. Injury incidence was calculated as the number of injured subjects per 100 subjects per year.

**Results**

Self-reported injuries within a one year period prior to testing have been described. The 106 subjects included in the analysis reported 26 injuries, including 20 preventable injuries, during a one year period.

Eighty four subjects (84/106, 79.2%) did not report any injury during a one year period. Eighteen subjects (18/106, 17.0%) reported one injury, and four subjects (4/106, 3.8%) reported two injuries during a one year period. Eighty nine subjects (89/106, 84.0%) did not report any preventable injury during a one year period. Fourteen subjects (14/106, 13.2%) reported one preventable injury, and three subjects (3/106, 2.8%) reported two preventable injuries during a one year period.

The frequency of injury for 3SFG subjects was 24.5 injuries/100 subjects/year and injury incidence was 20.8 injured subjects/100 subjects/year. The frequency of preventable injury for 3SFG subjects was 18.9 injuries/100 subjects/year and the injury incidence for preventable injuries was 16.0 injured subjects/100 subjects/year. Preventable musculoskeletal injuries comprised 76.9% of injuries that occurred during the year prior to laboratory testing, for this 3SFG sample.

The anatomic location and sub-location of injuries is described in Figure 1 and Table 1. The lower extremity was the most common location for injuries (13/26, 50.0% of injuries), and also when only preventable injuries were included in the analysis (12/20, 60.0% of preventable injuries). The shoulder and knee were common sub-locations for injuries (each 6/26, 23.1% of injuries), and also when only preventable injuries were included in the analysis (each 5/20, 25.0% of preventable injuries).

**Figure 1: Anatomic location of injuries during a one year period**

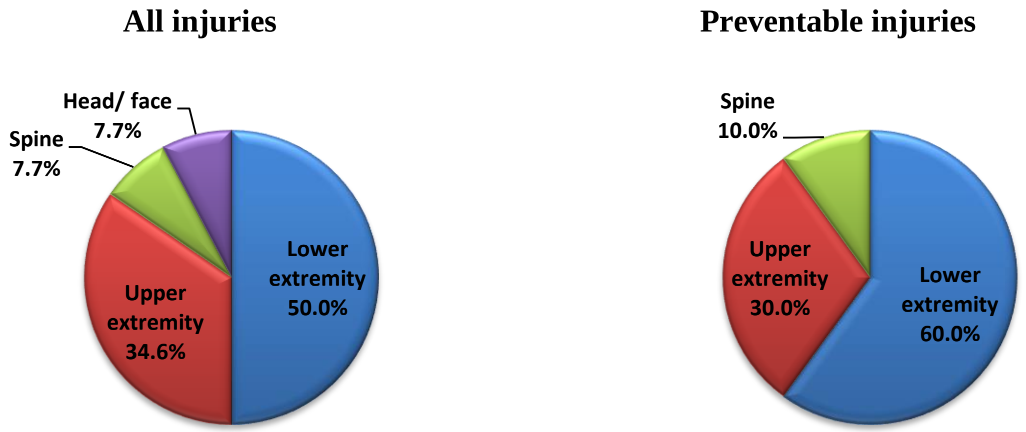


**Table 1: Anatomic sub-location of the injuries during a one year period**

| Injury anatomic location | Anatomic sub-location | All injuries | | Preventable injuries | |
|---|---|---|---|---|---|
| | | Number of injuries | Percent of injuries | Number of injuries | Percent of injuries |
| Lower extremity | Knee | 6 | 23.1 | 5 | 25.0 |
| | Ankle | 3 | 11.5 | 3 | 15.0 |
| | Thigh | 1 | 3.8 | 1 | 5.0 |
| | Lower leg | 2 | 7.7 | 2 | 10.0 |
| | Foot and toes | 1 | 3.8 | 1 | 5.0 |
| Upper extremity | Shoulder | 6 | 23.1 | 5 | 25.0 |
| | Upper arm | 1 | 3.8 | 1 | 5.0 |
| | Hand and fingers | 2 | 7.7 | 0 | 0.0 |
| Spine | Lumbopelvic | 2 | 7.7 | 2 | 10.0 |
| Head/ face | Eye | 1 | 3.8 | 0 | 0.0 |
| | Other | 1 | 3.8 | 0 | 0.0 |
| **Total** | | **26** | | **20** | |

Data regarding the cause of injuries is described in Table 2, and data about activity when injury occurred is described in Table 3 and Figure 2. Running and lifting were common injury causes. Running was the cause of 23.1% of injuries and lifting was the cause of 19.2% of injuries. When only preventable injuries were included in the analysis, running was the cause of 30.0% of preventable injuries and lifting was the cause of 25.0% of preventable injuries.

**Table 2: Cause of the injuries during a one year period**

| **Cause of injury** | **All injuries** | | **Preventable injuries** | |
|---|---|---|---|---|
| | **Number of injuries** | **Percent of injuries** | **Number of injuries** | **Percent of injuries** |
| Running | 6 | 23.1 | 6 | 30.0 |
| Lifting | 5 | 19.2 | 5 | 25.0 |
| Cutting | 3 | 11.5 | 3 | 15.0 |
| Direct Trauma | 3 | 11.5 | 0 | 0.0 |
| Landing | 2 | 7.7 | 2 | 10.0 |
| Crushing | 1 | 3.8 | 0 | 0.0 |
| Fall - Same Level | 1 | 3.8 | 0 | 0.0 |
| Marching | 1 | 3.8 | 1 | 5.0 |
| Other | 1 | 3.8 | 1 | 5.0 |
| Unknown | 3 | 11.5 | 2 | 10.0 |
| **Total** | **26** | | **20** | |

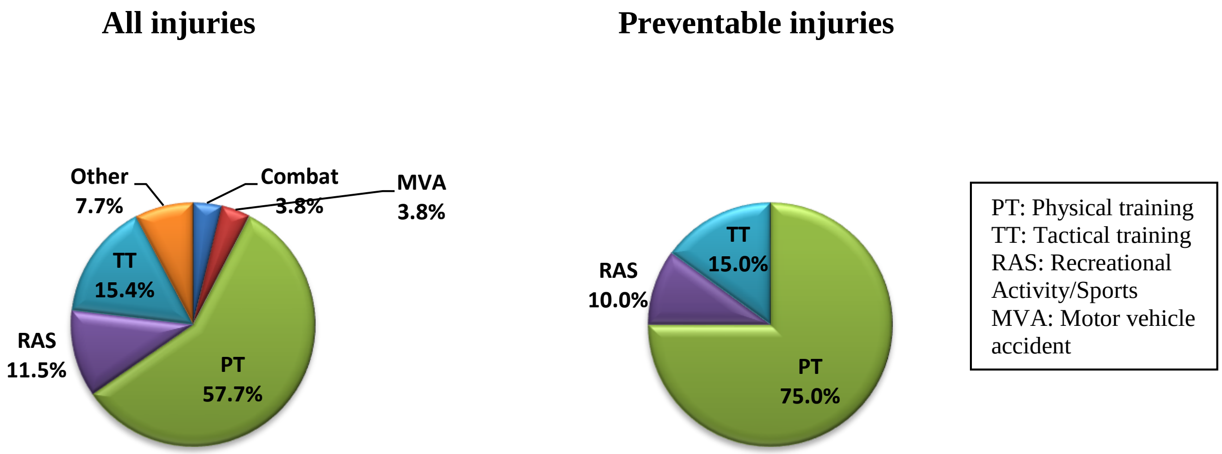
Physical training (PT) was the most reported activity for total injuries (PT Command Organized: 46.2%, PT Non Command Organized: 7.7%, PT Unknown: 3.8%) and preventable injuries (PT Command Organized: 60.0%, PT Non Command Organized: 10.0%, PT Unknown: 5.0%).

**Table 3: Activity when injury occurred during a one year period**

| **Activity** | **All injuries** | | **Preventable injuries** | |
|---|---|---|---|---|
| | **Number of injuries** | **Percent of injuries** | **Number of injuries** | **Percent of injuries** |
| Combat | 1 | 3.8 | 0 | 0.0 |
| Motor Vehicle Accident | 1 | 3.8 | 0 | 0.0 |
| *Physical Training – Command Organized | 12 | 46.2 | 12 | 60.0 |
| *Physical Training – Non Command Organized | 2 | 7.7 | 2 | 10.0 |
| *Physical Training – Unknown | 1 | 3.8 | 1 | 5.0 |
| Recreational Activity / Sports | 3 | 11.5 | 2 | 10.0 |
| Tactical Training | 4 | 15.4 | 3 | 15.0 |
| Other | 2 | 7.7 | 0 | 0.0 |
| **Total** | **26** | | **20** | |

*Denotes further classifications of physical training as activity when injury occurred

**Figure 2: Activity when injury occurred during a one year period**




Injury types are described in Table 4. Common injury types for total injuries were sprain (6/26, 23.1%), fracture and strain (each 3/26, 11.5%). When only preventable injuries were analyzed, common injury types were sprain (6/20, 30.0%) and strain (3/20, 15.0%).

**Table 4: Injury type during a one year period**

| Injury type | All injuries | | Preventable injuries | |
|---|---|---|---|---|
| | **Number of injuries** | **Percent of injuries** | **Number of injuries** | **Percent of injuries** |
| Sprain | 6 | 23.1 | 6 | 30.0 |
| Fracture | 3 | 11.5 | 1 | 5.0 |
| Strain | 3 | 11.5 | 3 | 15.0 |
| Bursitis | 2 | 7.7 | 2 | 10.0 |
| Meniscal | 2 | 7.7 | 2 | 10.0 |
| Pain / spasm / ache | 2 | 7.7 | 2 | 10.0 |
| Concussion | 1 | 3.8 | 0 | 0.0 |
| Dislocation | 1 | 3.8 | 0 | 0.0 |
| Impingement | 1 | 3.8 | 1 | 5.0 |
| Inflammation | 1 | 3.8 | 1 | 5.0 |
| Tendonitis / tenosynovitis / tendinopathy | 1 | 3.8 | 1 | 5.0 |
| Other | 2 | 7.7 | 1 | 5.0 |
| Unknown | 1 | 3.8 | 0 | 0.0 |
| **Total** | **26** | | **20** | |

Musculoskeletal injuries were classified according to their onset as acute (18/26, 69.2% of injuries), chronic (7/26, 26.9%), and unknown onset (1/26, 3.8%). Among preventable injuries, 13 injuries (13/20, 65.0%) were acute and seven injuries (7/20, 35.0%) were chronic. Musculoskeletal injuries were classified according to their mechanism as contact injuries (10/26, 38.5% of injuries), non-contact injuries (15/26, 57.7%), and unknown mechanism (1/26, 3.8%). Among preventable injuries, five injuries (5/20, 25.0%) were contact injuries, 14 injuries (14/20, 70.0%) were non-contact injuries, and one injury (1/20, 5.0%) had an unknown mechanism.

Eleven injuries (11/26, 42.3%) required some type of diagnostic testing (MRI, X-Ray or CT Scan). Ten injuries (10/26, 38.5%) required rehabilitation, six injuries (6/26, 23.1%) were prescribed pain medication, and 15 injuries (15/26, 57.7%) resulted in a prescription of rest. When preventable injuries were analyzed separately, six preventable injuries (6/20, 30.0%) required diagnostic testing. Ten preventable injuries (10/20, 50.0%) required rehabilitation, four preventable injuries (4/20, 20.0%) were prescribed pain medication, and 13 preventable injuries (13/20, 65.0%) resulted in a prescription of rest.

## Discussion

Musculoskeletal injuries in the SOF community continue to be a fiscal and personnel burden on the Force. The objective of this analysis was to describe the self-reported injury epidemiology of 3SFG Soldiers for one year prior to laboratory testing at the Warrior Human Performance Research Laboratory. As part of a human performance and injury prevention research project, this analysis initially identified the specific musculoskeletal injury patterns within the US Army Special Operations Forces community.

### *Injury Frequency and Incidence*

In the current investigation, the frequency of all musculoskeletal injury and injury incidence was 24.5 injuries/100 subjects/year and 20.8 injured subjects/100 subjects/year, respectively. The injury frequency is comparable with the injury frequency sustained by NSW personnel (approximately 11 to 38 injuries/100 subjects/year).[8] A study by Linenger et al[11] conducted among U.S. Navy Sea-Air-Land trainees described medical conditions and musculoskeletal injuries during Underwater Demolition/SEAL training (BUD/S). This study revealed 29.7 cases of musculoskeletal injuries per 100 trainee-months (approximately 300 injuries/100 subjects/year), which is higher than the injury frequency in the current study. A higher injury frequency (approximately 47 injuries/100 subjects/year) was also reported by Hollingsworth  in Marine Corps Special Warfare personnel during a strenuous pre-deployment training cycle.[7] In both the Linenger and Hollingsworth studies, injuries were described during specific training cycles, and perhaps higher frequencies of injuries were noted in both cases because certain injuries are more common during particular training cycles or evolutions. However, in the current study, there was individual variability among subjects in phase of physical and tactical training depending on their missions in upcoming deployments.

Previous research has evaluated injury incidence in the Army. A study by Knapik et al[12] described medical chart reviewed injuries among male Soldiers in an infantry battalion. Data abstracted included the diagnosis, body part, disposition and days of limited duty, with 51% of the Soldiers experiencing at least one injury. This incidence was much higher than the incidence calculated in the current study. Lauder et al[13] used data in a database for Army personnel in 1989-1994 to describe injuries related to sports and physical training. Diagnoses were coded using the ICD-9-CM. The rate of sports injuries was 38 per 10,000 person-years for men. This incidence rate cannot be directly compared to the cumulative incidence calculated from the current study, but both studies underscore the high risk of musculoskeletal injuries in the Army.

As a part of the University of Pittsburgh Injury Prevention and Performance Optimization research initiatives, we have conducted similar epidemiological analyses at two specific military populations: US Army 101st Airborne Division (Air Assault) and Naval Special Warfare personnel.[2,9] Based on those previous findings, 3SFG personnel sustained less injuries compared to the 101st Division Soldiers (41 injuries/100 subjects/year) and the Naval Special Warfare personnel (32 injuries/100 subjects/year). In addition to injury frequency and incidence of musculoskeletal injuries, the current study separated preventable and non-preventable injuries. Preventable musculoskeletal injuries comprise the majority of injuries. The results substantiate efforts to reduce injuries through well-designed physical training and combat training.

***Anatomic Location and Sub-location***

Injuries in the 3SFG were distributed among the lower extremity (50%), upper extremity (34.6%), spine (7.7%), and head/face (7.7%). The knee and shoulder were the most commonly injured sub-locations (both 25%), followed by the ankle (15%). These data were consistent with Hollingsworth[7] who reported the lower extremity (43%) as the most injured region in Marine

Corps Forces Special Operations personnel. Hollingsworth also identified the knee as the most commonly injured body region (24.4%), followed by the low back (17.1%), and ankle (14.6%). Contrary to the current findings, Lynch[6] reported a lesser percent of injuries to the lower extremity (32%) in 5SFG. Additionally, unlike the 3SFG, neck/back pain was the most common musculoskeletal diagnosis (31%) in the 5SFG, followed by the ankle (10%), shoulder (10%), and knee (10%). Compared to 3SFG, Peterson[8] identified a similar amount of lower extremity injuries (41%)  in a NSW personnel. However, unlike the current findings, the highest reported anatomical sub-location was the back/neck (26.5%), followed by the knee (20.9%), shoulder (18.8%), and foot/ankle (15.9%).

Musculoskeletal injuries in NSW personnel were also described by our group in an abstract.[9] We described medical chart reviewed as well as self-reported injuries. For medical chart reviewed injuries, the anatomic distribution was: upper extremity (45.7% of the injuries), lower extremity (34.3%), spine (17.1%) and torso (2.9%). For self-reported injuries, anatomic distribution was: lower extremity (47.2%), upper extremity (37.5%), spine (8.3%), torso (4.2%) and head/face (2.8%). The most common anatomic sub-location for medical chart reviewed injuries was the shoulder (28.6%), and for self-reported injuries was the ankle and shoulder (each 16.7%). The injury distributions revealed in the current study of 3SFG more closely resemble the self-reported data collected in the NSW study, with the highest proportion of injuries occurring in the lower extremity in both cases.

The results of the current study of 3SFG are variable in comparison with investigations of injury location in Army populations. Our research group conducted a study describing self-reported injuries among Army Soldiers in the 101$^{st}$ Airborne Division.[2] Bilateral injuries were counted twice in this report. The majority of injuries (62.6%) affected the lower extremity, which agrees with current study findings among 3SFG, where the majority of injuries (50.0%) also affected the lower extremity. In the study by Knapik et al.,[12] the greatest number of injuries involved the feet, whereas in the current study, the greatest proportion of injuries involved the knee and shoulder (each 23.1%). In the study by Lauder,[13] the most commonly injured body parts were the knee and the ankle. The most common injury type in men was anterior cruciate ligament injury. This finding about anatomic location is similar to the current study, but shoulder injuries were also common in the current study unlike the study by Lauder et al.

***Types of Injuries and Acute/Chronic***

In the current investigation, sprain was the most common injury type (23.1%), followed by fracture and strain (each 11.5%). Contrarily, the most common injury type in the study by Peterson[8] of NSW Operators was bursitis or impingement, followed by strains/sprains. In our study of NSW Operators, among medical chart reviewed injuries, strains (25.7%), pain/spasm/ache (20.0%), and fracture (11.4%) were common injury types. Among self-reported injuries, fracture (26.4%), sprain (13.9%), and strain (12.5%) were common injury types. In both the current study and our investigation of 101st Airborne Division (Air Assault) Soldiers,[2] sprain was the most common injury type (22.2% of injuries in the study among 101st Airborne Division (Air Assault) Soldiers, and 23.1% in the current study). On the other hand, in the investigation by Knapik et al[12] describing medical chart reviewed injuries among male Soldiers, musculoskeletal pain was the most common diagnosis.

The majority of musculoskeletal injuries in the current study were classified as acute (69.2%), which is in accordance with previous reports. Hollingsworth[7] reported a high proportion of traumatic injuries (54%) in a Marine Special Operations Company. Lauder et al[13] also demonstrated that for Army men and women combined, acute musculoskeletal injures accounted for 82% of all injuries, and that acute injuries made up a greater proportion of injuries as compared to chronic/overuse injuries. In the study by Linenger[11] of Navy SEAL trainees, overuse injuries accounted for > 90% of all injuries, but in the current study, acute injuries were more common. The fact that study by Linenger was conducted among trainees may explain the higher frequency of injuries as well as a greater proportion of overuse injuries, as compared to the current study which was not among trainees. The lower extremity was the most common location for injuries in both studies.

***Activities and Mechanisms of Injuries when Injuries Occurred***

Military injury epidemiology studies have demonstrated that physical training is a common activity during which musculoskeletal injuries frequency occur. The current investigation revealed that of the injuries classified as preventable, 75% injuries occurred during physical training (command organized, non-command organized, or unknown). In our investigation of injuries in Naval Special Warfare personnel, subjects reported participation in training for 40.0% of medical chart reviewed injuries, and 56.9% of self-reported injuries. Previous work by our investigated mechanism of injury in a group of 101st Airborne Division (Air Assault) Solders.[2] Like the current study of 3FGS, this study found that physical training, whether organized or independent, was the most common activity during which injuries occurred (48.5% of injuries in the study among 101st Airborne Division (Air Assault) Soldiers). Likewise, running was the most common cause of injury in both studies (34.3% of injuries in the study among 101st Airborne Division (Air Assault) Soldiers, and 23.1% in the current study).

Our findings conflict with previous work by Lauder et al,[13] who described only injuries related to sports and physical training using ICD-9-CM codes in Army personnel. In the case that an external cause of injury was recorded, only 11% of the subjects had injuries related to sports or physical training. In contrast, the current study included only men and was based on self-reported injury data not restricted to hospitalizations; and a much higher proportion of injuries (84.6%) was related to any type of training (physical or tactical) or recreational activity/ sports in the current study. This could be because injuries caused by training or sports in this young, active population typically are less likely to require hospitalization, causing a lower proportion of training injuries in the study by Lauder as compared to the current study.

***Limitations and Other Considerations***

The current investigation has limitations. The variability of injury frequency, incidence, anatomical location, type, and mechanism among studies may be explained by the variance in injury data collection methods utilized. Self-reported data are prone to issues with the effect of recall. However, in our case, the self-reported method may have captured injuries that medical records may have missed because of perceived reduced severity, and lack of hospitalization or doctor visit. The current investigation and the Hollingsworth study[7] utilized self-reported survey, while Lynch[6] and Peterson[8] utilized diagnostic categories (ICD-9CM) and medical record database. The authors acknowledge that there was imprecision in some diagnoses using ICD-9CM, and no injury location was available for some conditions. Also, the ICD-9CM did not describe injury types, injury cause, or activity when injury occurred. In our previous investigation on descriptive epidemiology in Naval Special Warfare personnel,[9] we have used both self-reported and medical chart reviews and found that medical chart reviews contained greater portion of injuries in spine region. Perhaps, neck/back pain (mostly muscular strain in the lumbopelvic regions) is so common that many operators did not remember or consider these as an injury during a self-report. To support this contention, the same investigation reported fracture as the most common injury type in self-reported injuries; but, third common injury type in medical chart review.[9] Muscular strain was the most common injury type in medical chart review.[9]

Second, definitions of injury are different among studies. For example, in the study by Hollingsworth[7] subjects were asked about pain or physical limitation due to musculoskeletal injury during the pre-deployment workup cycle. This definition is different from the definition used in our study, which defined an injury as a musculoskeletal injury that disrupted physical and/or training activities for at least one day whether or not medical attention was sought. The differences in injury frequency might be substantial as the majority of Marine operators (19/28 operators) with injuries continued their routine training regardless of injuries and reported no loss of training days. Injury frequency would likely be underestimated in the current study. Third, the current investigation is a part of comprehensive laboratory testing. Therefore, subjects must have met inclusion and exclusion criteria, which may have potentially excluded 3SFG Operators who suffered serious injuries from the study. Again, this would result in underestimation of actual injury counts.

**Conclusion**

Physical training is critical to the prevention of musculoskeletal injuries and optimization of human performance in SOF, yet a significant number of injuries are sustained during such training activities. The majority of these injuries are preventable, musculoskeletal injuries affecting the lower extremity, and the frequency and severity of these injuries may negatively impact force readiness. Implementation of injury prevention and human performance programming is critical to maintenance of the most important weapons system platform- the Operator.

## References


1. Hauret KG, Jones BH, Bullock SH, Canham-Chervak M, Canada S: Musculoskeletal injuries description of an under-recognized injury problem among military personnel. Am J Prev Med 2010; 38(1 Suppl): S61-70.
2. Sell TC, Abt JP, Crawford K, et al: Warrior Model for Human Performance and Injury Prevention: Eagle Tactical Athlete Program (ETAP) Part I. J Spec Oper Med 2010; 10(4): 2-21.
3. Jones BH, Bovee MW, Harris JM, 3rd, Cowan DN: Intrinsic risk factors for exercise-related injuries among male and female army trainees. Am J Sports Med 1993; 21(5): 705-10.
4. Shaffer RA, Brodine SK, Ito SI, Le AT: Epidemiology of illness and injury among U.S. Navy and Marine Corps female training populations. Mil Med 1999; 164(1): 17-21.
5. Jones BH, Cowan DN, Tomlinson JP, et al: Epidemiology of injuries associated with physical training among young men in the army. Med Sci Sports Exerc 1993; 25(2): 197-203.
6. Lynch JH, Pallis MP: Clinical Diagnoses in a Special Forces Group: The Musculoskeletal Burden. Journal of Special Operations Medicin 2008; 8(2): 76- 80.
7. Hollingsworth DJ: The prevalence and impact of musculoskeletal injuries during a pre-deployment workup cycle: survey of a Marine Corps special operations company. J Spec Oper Med 2009; 9(4): 11-5.
8. Peterson SN, Call MH, Wood DE, Unger DV, Sekiya JK: Injuries in Naval Special Warfare Sea, Air, and Land Personnel: Epidemiology and Surgical Management. Oper Tech Sports Med 2005; 13: 131-135.
9. Lovalekar M, Abt JP, Sell TC, et al. Descriptive Epidemiology of Musculoskeletal Injuries in Naval Special Warfare Personnel. American College of Sports Medicine Annual Meeting. 2013, Medicine & Science in Sports & Exercise: Indianapolis, IN. p. 63-66.
10. Powell EC, Sheehan KM, Christoffel KK: Firearm violence among youth: public health strategies for prevention. Ann Emerg Med 1996; 28(2): 204-12.
11. Linenger JM, Flinn S, Thomas B, Johnson CW: Musculoskeletal and Medical Morbidity Associated with Rigorous Physical Training. Clin J Sport Med 1993; 3(4): 229-34.
12. Knapik J, Ang P, Reynolds K, Jones B: Physical fitness, age, and injury incidence in infantry soldiers. J Occup Med 1993; 35(6): 598-603.
13. Lauder TD, Baker SP, Smith GS, Lincoln AE: Sports and physical training injury hospitalizations in the army. Am J Prev Med 2000; 18(3(Suppl)): 118-128.

**Injury Epidemiology of US Army Special Operations Forces**

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Musculoskeletal injuries (MSIs) have long been a problem in general purpose forces, yet anecdotal evidence provided by medical, human performance, and training leadership suggests MSIs are also a readiness impediment to Special Operations Forces (SOF). The advanced tactical and physical requirements of SOF and fiscal implications, including direct medical costs and manpower, of training SOF highlight the importance of mitigating MSIs. **Purpose:** To describe the injury epidemiology of SOF utilizing self-reported injury histories. **Methods:** A total of 106 SOF were enrolled (Age: 31.7 ± 5.3 years, Height: 179.0 ± 5.5 cm, Mass: 85.9 ± 10.9 kg) as a part of a comprehensive biomechanical, musculoskeletal, physiological, and nutritional laboratory test protocol. Self-reported musculoskeletal injury data were collected for one year prior to the date of laboratory testing and filtered for total injuries and those with the potential to be preventable based on injury type, activity, and mechanism. **Results:** The frequency of MSIs was 24.5 injuries/100 subjects/year for total injuries and 18.9 injuries/100 subjects/year for preventable injuries. The incidence of MSIs was 20.8 injured subjects/100 subjects/year for total injuries and 16.0 injured subjects/100 subjects/year for preventable injuries. Preventable MSIs comprised 76.9% of total injuries. The knee and shoulder were the most common reported locations for total injuries (each 23.1%) and preventable injuries (each 25.0%). Preventable MSIs were classified as 60% acute, 35% chronic/overuse, and 5.0% other/unknown. Physical training (PT) was the most reported activity for total injuries (PT Command Organized: 46.2%, PT Non Command Organized: 7.7%, PT Unknown: 3.8%) and preventable injuries (PT Command Organized: 60.0%, PT Non Command Organized: 10.0%, PT Unknown: 5.0%). **Conclusions:** MSIs impede optimal physical readiness and tactical training in the SOF community. The data suggest that a significant proportion of MSIs are classified as preventable and may be mitigated with human performance programs.

Opinions, interpretations, conclusions, and recommendations are those of the author and not necessarily endorsed by the Department of Defense, US Army, or US Army Special Operations Command.

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# University of Pittsburgh
***Institutional Review Board***

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## Memorandum

To: John Abt PhD
From: Richard Guido MD, Vice Chair
Date: 9/9/2013
IRB#: REN13080113 / PRO10120222
Subject: USASOC Injury Prevention/Performance Optimization Musculoskeletal Screening Initiative-Phases 1 and 2

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The Renewal for the above referenced research study was reviewed and approved by the Institutional Review Board, Committee A, which met on 9/3/2013.

Please note the following information:

The risk level designation is Greater Than Minimal.

Approval Date: 9/3/2013
Expiration Date: 9/2/2014

Please note that it is the investigator's responsibility to report to the IRB any unanticipated problems involving risks to subjects or others [see 45 CFR 46.103(b)(5) and 21 CFR 56.108(b)]. Refer to the IRB Policy and Procedure Manual regarding the reporting requirements for unanticipated problems which include, but are not limited to, adverse events. If you have any questions about this process, please contact the Adverse Events Coordinator at 412-383-1480.

The protocol and consent forms, along with a brief progress report must be resubmitted at least **one month** prior to the renewal date noted above as required by FWA00006790 (University of Pittsburgh), FWA00006735 (University of Pittsburgh Medical Center), FWA00000600 (Children's Hospital of Pittsburgh), FWA00003567 (Magee-Womens Health Corporation), FWA00003338 (University of Pittsburgh Medical Center Cancer Institute).

**Please be advised that your research study may be audited periodically by the University of Pittsburgh Research Conduct and Compliance Office.**

**DEPARTMENT OF THE ARMY**
**Womack Army Medical Center**
**Fort Bragg, North Carolina 28310**

REPLY TO
ATTENTION OF:

MCXC-DME-RES 15 April 2013

MEMORANDUM FOR: Pete Benson, Womack Army Medical Center, 2817 Reilly Road, Fort Bragg, NC 28310-7301

SUBJECT: [377905-4] USASOC Injury Prevention and Performance Optimization Research Initiative

1. Your Continuing Review (CR), dated 12 March 2013, was approved on 12 April 2013 by Full IRB Committee Review.

2. This study remains open for recruitment and enrollment. Documents approved by the IRB during this CR include:

- Consent Form - IRB Net 377905 Consent Stamped 2013 CR.pdf (UPDATED: 04/1/2013)
- Continuing Review/Progress Report - WAMC 2013 CR.docx (UPDATED: 04/1/2013)
- Protocol - IRB Net 377905 Protocol Clean 2013 CR.docx (UPDATED: 04/1/2013)

3. You must use the attached IRB approved and stamped consent form to enroll new participants. This consent expires 11 April 2014, when your next CR is due. If you wish to enroll subjects after this time, the IRB must issue a new approved stamped consent form.

4. As the Principal Investigator you are required by Federal, Department of Defense, and WAMC regulations to submit the following in a timely fashion to the IRB administrative team at wamcirbadmin@amedd.army.mil: (a) addenda delineating any changes in the protocol or study documents for IRB approval before changes are made, except when necessary to avoid imminent harm to subjects, in which case the change must be reported immediately, (b) notification of ALL unanticipated problems, involving risks to subjects or others, whether they are deemed serious or not, within 24 hours, (c) all serious study related adverse events within 24 hours, (d) continuing review due by 11 February 2014 (in order to allow IRB processing before the protocol expires on 11 April 2014) and (e) a final report at the completion of you study.

5. OTSG/MEDCOM Policy Memo 10-032 dated 30 April 2010 provides guidance for publication clearance requests. The release of materials resulting from your research in ANY way via ANY public forum requires prior publication clearance. All publication clearance must go through Operation Security, public affairs, and medical review before it is released. Please use the WAMC Publication Clearance document. Refer to the Research intranet website or contact the IRB administrative team for assistance as needed.

6. Included in your protocol is a description of the responsibilities of the Principal Investigator (PI), which you have signed. You must adhere to these responsibilities as the PI. If you discover that you will have to be absent from your duty station for any length of time that is greater than normal, e.g., deployment, contact the IRB administrative team immediately. A protocol can only stay active if an appropriately qualified and trained PI is assigned in your absence. As such, it is your responsibility to close the study with the IRB or transfer responsibility to another investigator before you leave.

7. If you have questions, the POC is Cheri Portee at 910-907-8964 or cheri.portee@us.army.mil. Please include your project title and reference number in all correspondence with this committee.

This document has been electronically signed in accordance with all applicable regulations, and a copy is retained within our records.