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PRINCIPAL INVESTIGATOR:
John Abt, PhD, ATC

CONTRACTING ORGANIZATION:
University of Pittsburgh

Pittsburgh, PA 15213-2303

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Abt, John; Lephart, Scott; Sell, Timothy; Lovalekar, Mita; Crawford, Kim; Benson, Pete; Kotwal, Russ; Morgan, Jeffrey; Kane, Shawn

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123 University Place
Pittsburgh, PA 15213-2303

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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 phases of a four phase research objective to ultimately improve physical readiness and mitigate unintentional musculoskeletal injuries.

15. SUBJECT TERMS
Injury prevention, physical readiness, tactical athlete, culturally-specific

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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 ± 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 Since Start of Project

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

Deliverables: 1) Abstract presented at the American College of Sports Medicine 2014. Sell, TC, Abt JP, Lovaleker M, Bozich A, Benson P, Morgan J, Lephart SM, FACSM. Injury Epidemiology of US Army Special Operations Forces. Medicine and Science in Sports and Exercise. 46(5S):759-769, 2014 (Appendix 1); 2) Manuscript published Military Medicine- Abt JP, Sell TC, Bozich AJ, Lovalekar MT, Kane SF, Benson PJ, Morgan JS, Lephart SM. Injury Epidemiology of US Army Special Operations Forces. Military Medicine. 179, 10:1106, 2014 (Appendix 2).

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

Phase 2 Aim 1: To prospectively identify biomechanical, musculoskeletal, physiological, and nutritional risk factors for injury in USASOC Operators
Status: Biomechanical, musculoskeletal, physiological, and nutritional data collection complete. Data queries received from the Armed Forces Health Surveillance Center. Data processing ongoing. Physiologically data initially processed and subjects stratified based on reported musculoskeletal injuries. Data will be processed to assess influence of biomechanical, musculoskeletal, and physiological variables to predict injuries to the lower back, shoulder, and lower extremity.
Revised Timeline/Deliverables: Data processing to continue through February 2015-March 2015. Manuscript preparation/submission: April-May, 2015.

The data captured during this aim were initially analyzed according to prospective injury status (all injuries) for all physiological variables. The initial data indicate no significant differences in physiological variables between subjects sustaining an injury and subjects who are injury free.

Variable		Injured group				Uninjured group				p-value (independent samples t-test)
		N	Mean	SD	Median	N	Mean	SD	Median	
Physiological Variables	Body Fat (% fat)	54	16.64	6.10	16.70	35	16.10	4.48	15.60	0.651
	Body Mass Index (mass/height^2)	54	26.64	2.80	26.19	35	26.18	2.27	25.83	0.416
	Height (cm)	54	179.53	5.54	180.00	35	180.78	4.95	180.34	0.280
	Anaerobic Capacity (w/kg)	53	8.34	1.10	8.54	35	8.38	0.87	8.68	0.840
	Anaerobic Power (w/kg)	53	14.05	1.60	14.16	35	14.16	1.27	14.22	0.721
	Mass (kg)	54	85.94	10.70	86.25	35	85.68	9.45	85.60	0.907
	Test Speed (mph)	53	8.68	0.87	8.60	34	8.91	0.85	8.90	0.230
	VO2Max (ml/kg/min)	53	49.58	4.74	49.60	34	51.35	4.65	51.70	0.090
	LT (% VO2Max)	49	79.56	9.85	79.60	27	78.50	10.28	77.50	0.661
	Test Time (s)	53	509.23	182.15	481.00	33	513.48	103.80	541.00	0.903

Data processing/analyses are ongoing. Additional analyses will be completed to compare group differences specific biomechanical and musculoskeletal variables in subjects sustaining lower back injuries,

Phase 2 Aim 2: To determine the relationship between previous history of unintentional musculoskeletal injury and biomechanical, musculoskeletal, physiological, and tactical characteristics
Status: Data collection complete. Manuscript preparation ongoing. Two abstracts submitted to the American College of Sports Medicine 2015.
Revised Timeline: Manuscript preparation/submission: November 2014-January 15.
Deliverables: Abstracts to be presented at American College of Sports Medicine May 2015. Kane SF, Abt JP, Kresta JY, Bakey JF, Parr JJ, Sell TC, Lephart SM. Residual Impact of Previous Injury on Musculoskeletal Characteristics in Special Forces Soldiers. American College of Sports Medicine Annual Meeting; May 26-30, 2015; San Diego, CA (Appendix 3) and Abt JP, Eagle SR, Kresta JY, Bakey JF, Sell TC, Kane SF, Lephart SM. Identification of Asymmetrical and Suboptimal Agonist/Antagonist Strength in a Cohort of Special Forces Soldiers. American College of Sports Medicine Annual Meeting; May 26-30,

2015; San Diego, CA (Appendix 4). Manuscript drafting ongoing and to be submitted to the Journal of Sports Rehabilitation (Appendix 5).

Phase 2 Aim 3: To identify suboptimal biomechanical, musculoskeletal, physiological, tactical, and nutritional characteristics for physical readiness in the USASOC Operator
Status: Biomechanical, musculoskeletal, physiological, injury, and nutritional data collection complete. Data processing ongoing. Abstract submitted and accepted to Academy of Nutrition and Dietetics. Baker R, Beals K, Darnell M, Abt J, Sell T, Morgan J, Kane S, Benson, P, Lephart S. Dietary Protein Intake and Protein Supplement Use of United States Army Special. Academy of Nutrition and Dietetics, 2014 (Appendix 5).
Revised Timeline/Deliverable: Data processing to continue through February 2015-March 2015. Manuscript preparation/submission: April-May, 2015.

Subject Demographics

	Age (Years)	Height (Inches)	Weight (Pounds)
USASOC (All)	32.0 ± 6.9	70.5 ± 2.6	187.4 ± 25.3
18 Series (3/5 SFG)	32.0 ± 5.3	70.5 ± 2.3	187.7 ± 23.3
SWCS (18 Series)	36.8 ± 8.1	70.5 ± 2.5	187.6 ± 22.9
Q-Course	28.6 ± 3.2	72.1 ± 2.3	184.5 ± 23.0
Pre Q-Course	23.3 ± 2.4	69.7 ± 3.9	175.5 ± 30.5
Support	34.5 ± 6.3	70.9 ± 2.5	192.4 ± 24.9
Other	36.0 ± 7.0	70.3 ± 2.3	193.3 ± 25.6

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 13.6±5.0%	3SFG Average BF 13.5±5.3%	QCourse Average BF 11.8±4.6%	SWCS Average BF NA	Pre QCourse Average BF 14.1±5.0%
Want to gain weight	15%	17%	38%	0%	22%
Consuming excess calories for weight gain	33%	33%	0%	--	62%
Consuming adequate calories to maintain weight	24%	22%	33%	--	13%
NOT consuming adequate calories to meet needs	42%	44%	67%	--	25%

	USASOC Average BF 21.9±6.5%	3SFG Average BF 20.0±6.5%	QCourse Average BF NA	SWCS Average BF 23.2±6.4%	Pre-QCourse Average BF 16.4±6.5%
Want to lose weight	42%	44%	0%	61%	19%
Consuming adequate calories for weight loss	59%	59%	--	64%	43%
Consuming adequate calories to maintain weight	16%	11%	--	9%	29%
Consuming excess calories	24%	30%	--	27%	29%

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

	16.1± 5.6%	15.3±5.6%	12.6±6.9%	20.5±6.7%	14.9±5.56%
Want to maintain current weight	42%	38%	62%	39%	59%
Consuming adequate calories for weight maintenance	19%	20%	0%	14%	23%
Consuming excess calories	32%	30%	40%	0%	32%
NOT consuming adequate calories to meet needs	48%	50%	60%	86%	45%

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)	33%	30%	25%	21%	62%
Met or exceeded the recommended amount of carbohydrate for general training needs (5-7 g/kg body weight/day)	19%	17%	25%	5%	43%

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.

Protein Requirements: 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)	30%	37%	13%	16%	30%
Fell below recommended range for protein requirements <1.2 g/kg bw/day	34%	26%	25%	53%	22%
Exceeded recommended range for protein requirements (>1.8 g/kg bw/day)	31%	31%	63%	26%	46%

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	5%	7%	0%	0%	14%
Met/exceeded protein needs, did NOT meet	40%	42%	50%	37%	19%

estimated energy needs					
Fell below recommended protein range, did NOT consume adequate calories	33%	35%	25%	53%	19%

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)	61%	67%	75%	37%	49%
Consumed less than 0.8g fat/kg body weight/day	26%	25%	13%	30%	14%
Exceeded 2.0g fat/kg body weight/day	13%	8%	13%	5%	38%
Exceeded estimated energy requirements w/ highest fat consumption	13% (1.59-4.7g fat/kg)	10% (1.59-3.25g fat/kg)	25% (1.86-2.75g 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	71%	76%	88%	53%	76%

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%	95%	75%	88%	89%
During Physical Training	75%	85%	67%	71%	97%
After Physical Training	99%	100%	67%	100%	97%

Type of Fluids Before PT	USASOC	3SFG	QCourse	SWCS	Pre-QCourse
Water	81%	78%	89%	80%	73%
Other	15% (coffee, low fat milk, fruit juice)	15% (coffee, low fat milk, fruit juice)	11%	2% (coffee)	13%
Sports Drinks	4%	7%	0%	0%	13%

Fluids During PT	USASOC	3SFG	QCourse	SWCS	Pre-QCourse
Water	93%	91%	100%	92%	100%
Sports Drinks	4%	5%	0%	8%	6%
Other	3%	4%	0%	0%	0%

Fluids After PT	USASOC	3SFG	QCourse	SWCS	Pre-QCourse
Water	88%	81%	100%	94%	75%
Other	9%	13% (protein drink, fruit juice, coffee)	0%	0%	36%
Sports Drinks	3%	6%	0%	12%	14%

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	49%	40%	100%	71%	65%
Pre-Training Type of Snack/Meal					
Contained both CHO and PRO	57%	30%	58%	57%	69%
Contained only PRO	9%	7%	8%	7%	3%
Contained only CHO	33%	20%	33%	36%	28%
N/A	1%	3%	--	--	--

Timing of Pre-Training Snack/Meal	USASOC	3SFG	QCourse	SWCS	Pre-QCourse
< 30 min prior to PT	24%	20%	33%	25%	19%
30-60 min prior to PT	55%	64%	50%	58%	81%
1-2 hours prior to PT	16%	13%	17%	8%	0%
2-3 hours prior to PT	5%	2 %	0%	8%	0%
3-4 hours prior to PT	0%	0%	0%	0%	0%

Timing and Content of Post-Training Snack/Meal	USASOC	3SFG	QCourse	SWCS	Pre-QCourse
Consumed post-training snack/meal	92%	79%	100%	100%	89%
Post-Training Type of Snack/Meal					
Contained both CHO and PRO	81%	84%	57%	75%	86%
Contained only PRO	13%	12%	29%	25%	8%
Contained only CHO	6%	3%	14%	0%	6%

Timing of Post-Training Snack/Meal	USASOC	3SFG	QCourse	SWCS	Pre-QCourse
< 30 min post PT	51%	51%	43%	47%	52%
30-60 min post PT	44%	46%	29%	47%	44%
1-2 hours post PT	4%	2%	29%	0%	0%
2-3 hours post PT	1%	0%	0%	6%	4%
3-4 hours post PT	1%	1%	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	71%	73%	58%	94%	73%

Breakdown of Dietary Supplements	USASOC	3SFG	QCourse	SWCS	Pre-QCourse
Whey/Protein Supplements	18%	17%	19%	17%	33%
Energy Drinks/Caffeine	4%	4%	4%	2%	3%
BCAA, Amino Acids	8%	7%	15%	2%	17%
Fish Oil, Omega 3 FA, Antioxidants	16%	14%	22%	22%	11%
Glucosamine, Chondroitin, Joint Stability	8%	9%	7%	5%	9%
Creatine	3%	3%	0%	5%	3%
Pre-workout (Jack 3D/C4 Nitric Oxide, NO Explode)	4%	5%	0%	5%	4%
Weight Loss, CLA	1%	1%	4%	0%	0%
Testosterone Boosters	1%	1%	0%	0%	1%
Multivitamin/Minerals	31%	28%	26%	37%	14%
Carbohydrate Gels/Recovery	6%	9%	0%	2%	0%
Herbal Supplements, Probiotics	1%	4%	4%	2%	4%

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	78.6	49.3	--
Top 25th %tile 3SFG	68.1	45.4	--
50th %tile 3SFG	61.3	40.0	--
Bottom 25th %tile 3SFG	52.2	36.1	--
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)	56.8 ± 12.3	38.7 ± 7.0	0.70 ± 0.15
18 Series (3/5 SFG)	60.8 ± 12.8	41.0 ± 7.2	0.70 ± 0.15
SWCS (18 Series)	55.8 ± 7.2	38.2 ± 5.8	0.70 ± 0.14
Q-Course	52.7 ± 12.4	38.7 ± 5.1	0.78 ± 0.25
Pre Q-Course	56.9 ± 9.8	38.0 ± 5.0	0.68 ± 0.10
Support	50.4 ± 13.5	36.2 ± 6.0	0.74 ± 0.15
Other	53.8 ± 10.6	35.7 ± 6.3	0.67 ± 0.14

LEFT

	IR (% BW)	ER (% BW)	ER/IR (Ratio)
Top 10th %tile 3SFG	79.1	48.9	--
Top 25th %tile 3SFG	64.9	43.8	--
50th %tile 3SFG	57.2	39.1	--
Bottom 25th %tile 3SFG	49.4	35.9	--
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)	55.5 ± 11.9	37.3 ± 6.8	0.68 ± 0.12
18 Series (3/5 SFG)	58.7 ± 12.6	40.3 ± 7.1	0.70 ± 0.12
SWCS (18 Series)	56.9 ± 8.5	37.9 ± 4.5	0.68 ± 0.10
Q-Course	54.0 ± 7.6	40.5 ± 8.0	0.76 ± 0.10
Pre Q-Course	55.1 ± 10.5	34.2 ± 4.7	0.62 ± 0.11
Support	48.9 ± 11.0	34.4 ± 6.1	0.72 ± 0.12
Other	53.3 ± 11.6	33.9 ± 5.3	0.65 ± 0.13

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

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	378.3 ± 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 10th Percentile of SBT-22.**

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	232.3	423.0	--
Top 25th %tile 3SFG	214.8	355.7	--
50th %tile 3SFG	194.0	297.9	--
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)	190.1 ± 33.1	291.0 ± 73.5	1.54 ± 0.35
18 Series (3/5 SFG)	192.8 ± 35.0	310.8 ± 78.4	1.63 ± 0.38
SWCS (18 Series)	185.8 ± 29.3	293.1 ± 41.9	1.61 ± 0.34
Q-Course	203.7 ± 43.6	310.9 ± 86.0	1.53 ± 0.23
Pre Q-Course	190.6 ± 29.4	270.1 ± 66.4	1.42 ± 0.31
Support	189.7 ± 31.7	270.9 ± 75.3	1.43 ± 0.33
Other	180.3 ± 31.0	268.8 ± 58.5	1.5 ± 0.26

***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	163.7	298.6	--
Top 25th %tile 3SFG	143.7	268.1	--
50th %tile 3SFG	128.4	244.6	--
Bottom 25th %tile 3SFG	115.1	206.6	--
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)	124.9 ± 24.3	233.1 ± 44.1	0.54 ± 0.10
18 Series (3/5 SFG)	131.1 ± 23.3	241.2 ± 46.5	0.55 ± 0.11
SWCS (18 Series)	124.0 ± 17.2	223.9 ± 39.7	0.57 ± 0.11
Q-Course	128.0 ± 10.7	249.5 ± 21.1	0.51 ± 0.03
Pre Q-Course	120.7 ± 23.5	241.7 ± 41.6	0.50 ± 0.07
Support	115.9 ± 23.3	219.1 ± 45.7	0.54 ± 0.10
Other	121.1 ± 30.5	217.5 ± 37.8	0.55 ± 0.09

LEFT

	Flexion (% BW)	Extension (% BW)	Flex/Ext (Ratio)
Top 10th %tile 3SFG	160.8	289.0	--
Top 25th %tile 3SFG	142.1	262.1	--
50th %tile 3SFG	125.0	224.7	--
Bottom 25th %tile 3SFG	110.7	204.2	--
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)	120.7 ± 23.8	225.3 ± 41.9	0.54 ± 0.08
18 Series (3/5 SFG)	127.5 ± 24.7	231.8 ± 42.9	0.55 ± 0.08
SWCS (18 Series)	123.3 ± 16.9	224.6 ± 32.4	0.56 ± 0.07
Q-Course	124.2 ± 13.4	234.2 ± 16.2	0.53 ± 0.09

Pre Q-Course	118.0	±	25.9	231.9	±	42.9	0.51	±	0.08
Support	113.1	±	22.1	210.1	±	43.9	0.54	±	0.09
Other	110.6	±	20.6	214.7	±	40.9	0.52	±	0.06

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

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).**

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	119.4	90.0	123.7
Top 25th %tile 3SFG	105.7	66.0	117.0
50th %tile 3SFG	98.7	60.0	109.7
Bottom 25th %tile 3SFG	92.0	50.0	102.3
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)	105.2 ± 26.6	61.3 ± 15.7	107.1 ± 15.9
18 Series (3/5 SFG)	107.0 ± 30.9	61.7 ± 18.2	106.1 ± 18.6
SWCS (18 Series)	96.6 ± 9.1	56.2 ± 8.2	110.5 ± 6.9
Q-Course	97.8 ± 13.3	54.5 ± 11.4	107.1 ± 5.3
Pre Q-Course	105.1 ± 11.1	61.1 ± 7.8	111.4 ± 10.2
Support	99.6 ± 7.4	59.6 ± 11.2	109.7 ± 8.5
Other	111.8 ± 39.6	66.2 ± 19.5	101.8 ± 20.5

LEFT

	External Rotation (degrees)			Internal Rotation (degrees)			PST (degrees)		
Top 10th %tile 3SFG	120.8			83.6			124.0		
Top 25th %tile 3SFG	104.3			68.3			118.0		
50th %tile 3SFG	95.3			61.5			110.0		
Bottom 25th %tile 3SFG	90.0			55.0			104.3		
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)	102.8	±	27.8	64.9	±	14.0	107.6	±	16.5
18 Series (3/5 SFG)	104.2	±	31.9	64.2	±	15.6	107.1	±	18.3
SWCS (18 Series)	93.4	±	12.7	64.0	±	10.2	111.5	±	6.8
Q-Course	100.7	±	10.9	61.6	±	15.5	109.1	±	6.5
Pre Q-Course	100.6	±	12.9	65.8	±	8.8	109.6	±	14.8
Support	97.8	±	9.9	63.9	±	10.1	109.5	±	7.0
Other	110.8	±	40.8	68.5	±	17.2	102.8	±	22.8

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

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).**

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	3.5	7.5
Top 25th %tile 3SFG	9.8	13.5
50th %tile 3SFG	19.5	20.0
Bottom 25th %tile 3SFG	28.1	29.3
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)	21.5 ± 21.7	23.5 ± 22.1
18 Series (3/5 SFG)	24.8 ± 25.4	26.5 ± 25.5
SWCS (18 Series)	15.4 ± 9.7	19.2 ± 8.9
Q-Course	10.6 ± 9.4	12.1 ± 8.2
Pre Q-Course	17.2 ± 12.2	19.0 ± 12.7
Support	15.8 ± 9.8	16.7 ± 8.7
Other	27.2 ± 28.1	30.8 ± 29.9

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	17.3
50th %tile 3SFG	13.3	14.5
Bottom 25th %tile 3SFG	11.0	12.0
Clinical Range	10.0-25.0	10.0-25.0
USASOC (All)	14.1 ± 3.9	14.5 ± 4.0
18 Series (3/5 SFG)	13.7 ± 4.1	14.2 ± 4.4
SWCS (18 Series)	15.2 ± 4.1	16.3 ± 3.6
Q-Course	12.9 ± 2.1	13.6 ± 2.9
Pre Q-Course	13.9 ± 4.9	13.7 ± 4.3
Support	14.9 ± 3.4	15.2 ± 3.3
Other	14.4 ± 3.1	14.7 ± 3.4

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).**

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).**

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	0.0231	0.1178	0.2757	0.3087
Top 25th %tile 3SFG	0.0268	0.1242	0.3087	0.3391
50th %tile 3SFG	0.0310	0.1323	0.3381	0.3662
Bottom 25th %tile 3SFG	0.0339	0.1414	0.3589	0.3850
Athlete*	0.0300	0.1400	0.3939	0.3500
USASOC (All)	0.0320 ± 0.0066	0.1306 ± 0.0112	0.3324 ± 0.0403	0.3633 ± 0.0392
18 Series (3/5 SFG)	0.0307 ± 0.0058	0.1326 ± 0.0117	0.3349 ± 0.0425	0.3636 ± 0.0420
SWCS (18 Series)	0.0309 ± 0.0045	0.1285 ± 0.0105	0.3185 ± 0.0377	0.3522 ± 0.0447
Q-Course	0.0325 ± 0.0059	0.1308 ± 0.0081	0.3390 ± 0.0230	0.3600 ± 0.0037
Pre Q-Course	0.0334 ± 0.0073	0.1307 ± 0.0102	0.3356 ± 0.0338	0.3621 ± 0.0330
Support	0.0343 ± 0.0068	0.1273 ± 0.0128	0.3274 ± 0.0469	0.3723 ± 0.0430
Other	0.0331 ± 0.0081	0.1289 ± 0.0090	0.3327 ± 0.0372	0.3612 ± 0.0411

LEFT

	MLSI	APSI	VSI	DPSI
Top 10th %tile 3SFG	0.0223	0.1191	0.2717	0.2995
Top 25th %tile 3SFG	0.0241	0.1240	0.2992	0.3277
50th %tile 3SFG	0.0281	0.1326	0.3283	0.3531
Bottom 25th %tile 3SFG	0.0322	0.1380	0.3524	0.3790
USASOC (All)	0.0297 ± 0.0062	0.1294 ± 0.0109	0.3274 ± 0.0391	0.3538 ± 0.0374
18 Series (3/5 SFG)	0.0286 ± 0.0058	0.1315 ± 0.0096	0.3266 ± 0.0429	0.3538 ± 0.0406
SWCS (18 Series)	0.0298 ± 0.0062	0.1272 ± 0.0133	0.3121 ± 0.0328	0.3389 ± 0.0302
Q-Course	0.0303 ± 0.0054	0.1308 ± 0.0085	0.3434 ± 0.0221	0.3690 ± 0.0208
Pre Q-Course	0.0319 ± 0.0085	0.1307 ± 0.0094	0.3364 ± 0.0299	0.3628 ± 0.0281
Support	0.0298 ± 0.0056	0.1266 ± 0.0128	0.3277 ± 0.0429	0.3529 ± 0.0428
Other	0.0305 ± 0.0047	0.1254 ± 0.0117	0.3241 ± 0.0364	0.3493 ± 0.0353

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

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	20.6	34.6	-1.4	20.0	44.2	6.3
Top 25th %tile 3SFG	24.2	30.3	-4.7	24.7	39.2	2.1
50th %tile 3SFG	30.0	25.4	-9.2	33.0	34.2	-3.0
Bottom 25th %tile 3SFG	34.6	19.3	-12.5	41.3	27.2	-7.2
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)	29.8 ± 6.7	26.6 ± 6.3	-8.9 ± 5.4	32.3 ± 9.3	35.1 ± 7.1	-2.8 ± 6.6
18 Series (3/5 SFG)	30.1 ± 7.0	25.3 ± 6.9	-8.7 ± 5.5	33.1 ± 9.7	33.5 ± 7.7	-2.6 ± 6.4
SWCS (18 Series)	26.8 ± 6.5	28.1 ± 6.2	-8.0 ± 3.9	27.3 ± 9.3	36.0 ± 5.6	-0.1 ± 5.9
Q-Course	28.1 ± 5.8	25.0 ± 5.0	-8.5 ± 4.5	29.4 ± 7.8	33.1 ± 5.9	-1.4 ± 5.4
Support	29.8 ± 6.4	29.4 ± 4.7	-9.0 ± 5.1	32.0 ± 8.8	38.8 ± 5.8	-3.9 ± 6.3
Other	31.8 ± 6.5	27.8 ± 5.0	-10.1 ± 6.6	34.9 ± 8.5	36.6 ± 5.6	-4.6 ± 8.0

LEFT HUMERAL ELEVATION

	90 Degrees			120 Degrees		
	IR(+)/ER (-)	UR (+)/DR (-)	AT(-)/PT (+)	IR(+)/ER (-)	UR (+)/DR (-)	AT(-)/PT (+)
Top 10th %tile 3SFG	22.0	33.3	0.6	20.0	40.9	6.5
Top 25th %tile 3SFG	25.6	29.5	-3.2	24.9	37.4	3.2
50th %tile 3SFG	30.5	25.0	-8.0	30.8	32.5	-1.6
Bottom 25th %tile 3SFG	34.8	19.4	-11.8	36.1	27.7	-5.4
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*	43.5	--	-9.9	47.5	40.7	-8.1
USASOC (All)	30.3 ± 6.5	25.6 ± 5.7	-7.9 ± 5.4	30.8 ± 8.4	34.0 ± 6.4	-1.4 ± 6.2
18 Series (3/5 SFG)	30.1 ± 6.0	24.5 ± 6.2	-7.5 ± 5.7	31.2 ± 8.6	32.7 ± 6.9	-1.5 ± 6.3
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 ± 5.5	-1.1 ± 5.8
Support	30.4 ± 7.4	28.0 ± 5.5	-7.5 ± 4.7	29.6 ± 7.9	36.5 ± 6.1	-0.5 ± 5.7
Other	31.6 ± 7.5	26.3 ± 4.3	-9.1 ± 6.7	32.6 ± 9.4	35.0 ± 4.8	-3.7 ± 7.8

RIGHT HUMERAL DEPRESSION

	90 Degrees			120 Degrees		
	IR(+)/ER (-)	UR (+)/DR (-)	AT(-)/PT (+)	IR(+)/ER (-)	UR (+)/DR (-)	AT(-)/PT (+)
Top 10th %tile 3SFG	18.9	34.9	0.4	18.9	45.4	7.3
Top 25th %tile 3SFG	23.3	30.9	-3.3	25.2	38.4	3.5
50th %tile 3SFG	30.5	26.7	-6.9	34.5	34.8	-1.3
Bottom 25th %tile 3SFG	35.6	20.4	-11.2	42.5	27.0	-5.4
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)	29.1 ± 7.1	27.3 ± 6.6	-7.1 ± 5.9	32.5 ± 9.9	35.1 ± 7.3	-1.5 ± 6.8
18 Series (3/5 SFG)	29.4 ± 7.4	26.1 ± 6.8	-6.9 ± 5.8	33.5 ± 10.4	33.5 ± 7.8	-1.2 ± 6.3
SWCS (18 Series)	25.8 ± 7.2	29.0 ± 5.7	-5.9 ± 4.5	26.8 ± 8.2	36.7 ± 5.7	1.5 ± 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	29.0 ± 6.6	30.1 ± 5.8	-7.5 ± 5.8	31.9 ± 9.4	38.6 ± 6.3	-2.6 ± 7.1
Other	30.9 ± 6.6	27.8 ± 6.7	-8.6 ± 7.5	34.1 ± 9.5	36.9 ± 5.8	-3.5 ± 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	20.7	33.1	2.9	18.3	42.0	7.7
Top 25th %tile 3SFG	23.7	29.7	-1.4	25.1	37.2	4.2
50th %tile 3SFG	28.2	25.4	-6.5	30.5	33.2	-0.3
Bottom 25th %tile 3SFG	33.2	20.3	-10.3	35.7	27.0	-4.1
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)	28.9 ± 6.6	26.4 ± 5.6	-6.2 ± 5.7	30.4 ± 8.6	34.1 ± 6.5	-0.1 ± 6.3
18 Series (3/5 SFG)	28.4 ± 6.1	25.3 ± 5.9	-5.8 ± 5.9	30.8 ± 8.9	32.8 ± 6.9	-0.3 ± 6.3
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	29.1 ± 7.0	28.7 ± 5.0	-5.5 ± 5.1	29.3 ± 8.3	36.4 ± 6.3	0.7 ± 5.5
Other	30.1 ± 7.5	27.2 ± 5.3	-7.8 ± 6.9	32.2 ± 9.4	35.6 ± 5.2	-2.7 ± 7.5

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

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	56.9	5 to -5
Top 25th %tile 3SFG	50.1	10 to -10
50th %tile 3SFG	42.4	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)	42.4 ± 9.5	-3.4 ± 3.4
18 Series (3/5 SFG)	43.5 ± 9.6	-4.0 ± 3.5
SWCS (18 Series)	38.6 ± 6.8	-2.2 ± 2.9
Q-Course	47.2 ± 7.7	-3.6 ± 2.0
Support	42.1 ± 11.1	-2.7 ± 4.1
Other	39.0 ± 7.9	-2.9 ± 2.7

LEFT

	Hip Flexion @ Initial Contact (degrees)	Hip Abduction @ Initial Contact (degrees)
Top 10th %tile 3SFG	55.2	5 to -5
Top 25th %tile 3SFG	50.2	10 to -10
50th %tile 3SFG	43.8	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)	43.2 ± 9.8	-4.3 ± 3.7
18 Series (3/5 SFG)	44.0 ± 9.5	-4.3 ± 3.5
SWCS (18 Series)	40.3 ± 7.3	-4.7 ± 3.3
Q-Course	47.1 ± 8.1	-6.3 ± 4.5
Support	43.0 ± 12.3	-3.4 ± 4.4
Other	40.7 ± 8.9	-4.5 ± 3.1

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	37.1	5 to -5	110.0
Top 25th %tile 3SFG	30.4	10 to -10	99.8
50th %tile 3SFG	25.2	15 to -15	89.5
Bottom 25th %tile 3SFG	20.6	20 to -20	83.0
Clinical Value	--	0.0	--
Triathletes	29.9 ± 8.7	5.6 ± 3.8	82.4 ± 11.9
USASOC (All)	24.9 ± 7.5	4.9 ± 5.2	92.3 ± 14.9
18 Series (3/5 SFG)	25.8 ± 7.7	5.2 ± 5.3	92.2 ± 15.1
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	23.9 ± 6.9	5.1 ± 4.4	91.1 ± 15.5
Other	23.2 ± 7.9	4.1 ± 5.4	93.0 ± 10.7

LEFT

	Knee Flexion @ Initial Contact (degrees)	Knee Valgus @ Initial Contact (degrees)	Maximum Knee Flexion (degrees)
Top 10th %tile 3SFG	36.6	5 to -5	113.2
Top 25th %tile 3SFG	30.5	10 to -10	99.7
50th %tile 3SFG	25.2	15 to -15	87.7
Bottom 25th %tile 3SFG	20.2	20 to -20	79.7
Clinical Value	--	0.0	--
Triathletes	34.8 ± 9.5	6.2 ± 9.1	84.8 ± 8.3
USASOC (All)	25.3 ± 7.7	5.4 ± 6.4	90.5 ± 15.6
18 Series (3/5 SFG)	25.6 ± 8.4	5.2 ± 6.4	90.0 ± 15.4
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	24.9 ± 6.9	4.9 ± 6.4	89.9 ± 17.4
Other	24.7 ± 7.3	7.1 ± 7.3	91.6 ± 11.1

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	142.6
Top 25th %tile 3SFG	166.6
50th %tile 3SFG	195.5
Bottom 25th %tile 3SFG	240.5
Triathletes	210.8 ± 48.1
USASOC (All)	209.8 ± 70.7
18 Series (3/5 SFG)	212.0 ± 72.1
SWCS (18 Series)	194.5 ± 61.8
Q-Course	238.2 ± 84.6
Support	195.8 ± 54.7
Other	214.6 ± 80.2

LEFT

	Peak Vertical GRF (%BW)
Top 10th %tile 3SFG	145.4
Top 25th %tile 3SFG	165.0
50th %tile 3SFG	189.4
Bottom 25th %tile 3SFG	225.0
Triathletes	224.3 ± 63.2
USASOC (All)	194.7 ± 53.8
18 Series (3/5 SFG)	200.1 ± 53.0
SWCS (18 Series)	189.1 ± 61.8
Q-Course	200.8 ± 67.4
Support	180.9 ± 45.6
Other	187.6 ± 56.5

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	9.2	--	--
Top 25th %tile 3SFG	12.9	--	--
50th %tile 3SFG	16.8	--	--
Bottom 25th %tile 3SFG	20.4	--	--
Athlete*	15.42	--	--
Triathletes	12.31 ± 4.37	--	--
USASOC (All)	18.15 ± 6.79	70.50 ± 2.63	187.41 ± 25.33
18 Series (3/5 SFG)	16.59 ± 5.57	70.54 ± 2.28	187.74 ± 23.31
SWCS (18 Series)	20.69 ± 5.42	70.45 ± 2.46	187.58 ± 22.88
Q-Course	12.52 ± 3.40	72.11 ± 2.30	184.46 ± 23.01
Pre Q-Course	14.98 ± 4.58	69.67 ± 3.90	175.54 ± 30.46
Support	21.24 ± 7.70	70.89 ± 2.49	192.42 ± 24.90
Other	22.64 ± 8.08	70.28 ± 2.30	193.29 ± 26.61

***NMRL Database of Professional Football Players**

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	9.3
Top 25th %tile 3SFG	14.9	9.0
50th %tile 3SFG	13.9	8.5
Bottom 25th %tile 3SFG	13.0	7.9
Athlete*	16.86 ± 1.35	10.45 ± 0.56
Triathletes	13.75 ± 1.05	9.25 ± 0.70
USASOC (All)	13.81 ± 1.33	8.09 ± 1.09
18 Series (3/5 SFG)	13.93 ± 1.42	8.41 ± 0.86
SWCS (18 Series)	14.01 ± 1.36	7.84 ± 1.00
Q-Course	14.65 ± 0.83	8.56 ± 0.89
Pre Q-Course	13.56 ± 1.15	8.35 ± 0.94
Support	13.59 ± 1.42	7.43 ± 1.26
Other	13.59 ± 1.13	7.58 ± 1.24

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

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

Phase 3: To validate THOR3's human performance program to modify injury mitigating and human performance characteristics identified in Phase 2
Status: Ongoing. Planning meeting to be held December 2014 with THOR3 personnel to outline logistics with planned implementation in January 2015.
Revised Timeline: January 2015-June 2015.
Deliverables: Abstract to be submitted to American College of Sports Medicine. Manuscript to be submitted to the Journal of Strength and Conditioning Research.

Administrative

A no cost extension was approved extending the project to end date to June 30, 2015 (Appendix 6)

Personnel

COL Shawn Kane, MD, Command Surgeon, was named USASOC PI. Anthony Boizch, MS, resigned his position effective August 14, 2014. Julie Kresta, PhD, resigned her position to be effective December 5, 2014. New position announcements have been created and will be posted for a national search to replace Anthony and Julie.

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 August 11, 2014. The next expiration is August 11, 2015 (Appendix 7).

Womack Army Medical Center

Continuing review was submitted to Womack Army Medical Center and was approved March 14, 2014. The next expiration is April 15, 2015 for phases 1 and 2. (Appendix 8). Phase 3 IRB was approved June 13, 2014 and will expire June 12, 2015 (Appendix 9)

Reportable Outcomes

Abstracts

Sell, TC, Abt JP, Lovaleker M, Bozich A, Benson P, Morgan J, Lephart SM, FACSM. Injury Epidemiology of US Army Special Operations Forces. Medicine and Science in Sports and Exercise. 46(5S):759-769, 2014.

Kane SF, Abt JP, Kresta JY, Bakey JF, Parr JJ, Sell TC, Lephart SM. Residual Impact of Previous Injury on Musculoskeletal Characteristics in Special Forces Soldiers. American College of Sports Medicine Annual Meeting; May 26-30, 2015; San Diego, CA (In Review).

Abt JP, Eagle SR, Kresta JY, Bakey JF, Sell TC, Kane SF, Lephart SM. Identification of Asymmetrical and Suboptimal Agonist/Antagonist Strength in a Cohort of Special Forces Soldiers. American College of Sports Medicine Annual Meeting; May 26-30, 2015; San Diego, CA (In Review).

Manuscripts

Abt JP, Sell TC, Bozich AJ, Lovalekar MT, Kane SF, Benson PJ, Morgan JS, Lephart SM. Injury Epidemiology of US Army Special Operations Forces. Military Medicine. 179, 10:1106, 2014.

Residual Impact of Previous Injury on Musculoskeletal Characteristics in Special Forces Soldiers. Journal of Sport Rehabilitation. In Preparation.

Grant Submissions

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 (Approval Pending).

Conclusions

Not applicable

References
Not applicable

Appendices

1. Sell, TC, Abt JP, Lovaleker M, Bozich A, Benson P, Morgan J, Lephart SM, FACSM. Injury Epidemiology of US Army Special Operations Forces. Medicine and Science in Sports and Exercise. 46(5S):759-769, 2014.
2. Abt JP, Sell TC, Bozich AJ, Lovalekar MT, Kane SF, Benson PJ, Morgan JS, Lephart SM. Injury Epidemiology of US Army Special Operations Forces. Military Medicine. 179, 10:1106, 2014.
3. Kane SF, Abt JP, Kresta JY, Bakey JF, Parr JJ, Sell TC, Lephart SM. Residual Impact of Previous Injury on Musculoskeletal Characteristics in Special Forces Soldiers. American College of Sports Medicine Annual Meeting; May 26-30, 2015; San Diego, CA (In Review).
4. Abt JP, Eagle SR, Kresta JY, Bakey JF, Sell TC, Kane SF, Lephart SM. Identification of Asymmetrical and Suboptimal Agonist/Antagonist Strength in a Cohort of Special Forces Soldiers. American College of Sports Medicine Annual Meeting; May 26-30, 2015; San Diego, CA (In Review).
5. Baker R, Beals K, Darnell M, Abt J, Sell T, Morgan J, Kane S, Benson, P, Lephart S. Dietary Protein Intake and Protein Supplement Use of United States Army Special. Academy of Nutrition and Dietetics, 2014.
6. No Cost Extension Approval
7. University of Pittsburgh Continuing Review Approval
8. Womack Army Medical Center Continuing Review Approval
9. Womack Army Medical Center Original Approval- Phase 3

Injury Epidemiology of US Army Special Operations Forces

Timothy Sell, John Abt, Mita Lovalekar, Tony Bozich, Peter Benson, Jeffrey Morgan, Scott Lephart FACSM

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.

Supported by USAMRMC #W81XWH-11-2-0020

MILITARY MEDICINE, 179, 10:1106, 2014

Injury Epidemiology of U.S. Army Special Operations Forces

John P. Abt, PhD*; Timothy C. Sell, PhD*; Mita T. Lovalekar, PhD*; Karen A. Keenan, PhD*; Anthony J. Bozich, MS*; LTC Jeffrey S. Morgan, MC USA†; COL Shawn F. Kane, MC USA†; COL Peter J. Benson, MC USA†; Scott M. Lephart, PhD*

ABSTRACT Musculoskeletal injuries have long been a problem in general purpose forces, yet anecdotal evidence provided by medical, human performance, and training leadership suggests musculoskeletal injuries are also a readiness impediment to Special Operations Forces (SOF). The purpose of this study was to describe the injury epidemiology of SOF utilizing self-reported injury histories. Data were collected on 106 SOF (age: 31.7 ± 5.3 years, height: 179.0 ± 5.5 cm, mass: 85.9 ± 10.9 kg) for 1 year before 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. The frequency of musculoskeletal injuries was 24.5 injuries per 100 subjects per year for total injuries and 18.9 injuries per 100 subjects per year for preventable injuries. The incidence of musculoskeletal injuries was 20.8 injured subjects per 100 subjects per year for total injuries and 16.0 injured subjects per 100 subjects per year for preventable injuries. Preventable musculoskeletal injuries comprised 76.9% of total injuries. Physical training (PT) was the most reported activity for total/preventable injuries (PT Command Organized: 46.2%/60.0%, PT Noncommand Organized: 7.7%/10.0%, PT Unknown: 3.8%/5.0%). Musculoskeletal injuries impede optimal physical readiness/tactical training in the SOF community. The data suggest a significant proportion of injuries are classified as preventable and may be mitigated with human performance programs.

INTRODUCTION

Despite significant study of injury epidemiology in U.S. military personnel,[1–5] limited published data have described injury patterns of U.S. 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 U.S. Army Special Operations Command (USASOC). The advanced tactical and physical requirements of USASOC personnel, and fiscal implications, including direct medical costs and manpower, of training USASOC personnel, 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 required surgery and had associated loss of time because of surgery and rehabilitation.[8] Similarly, of 87 Marine Corps Special Operations personnel surveyed, 28 sustained at least one injury during a predeployment 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 U.S. 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 were 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] the 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 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, because of 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 analysis was to

*Department of Sports Medicine and Nutrition, Neuromuscular Research Laboratory, University of Pittsburgh, 3830 South Water Street, Pittsburgh, PA 15203.

†United States Army Special Operations Command (AOMD), 2929 Desert Storm Drive (Stop A), Fort Bragg, NC 28310.

The opinions, interpretations, conclusions, and recommendations are those of the author and not necessarily endorsed by the Department of Defense, U.S. Army, or U.S. Army Special Operations Command.

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describe the injury epidemiology of the 3rd SOF 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 of USASOC's physical training (PT) program to reduce musculoskeletal injuries and enhance force readiness.

METHODS

Human subject protections approvals were obtained by the appropriate necessary civilian and military review boards. Musculoskeletal injury data were captured from individual participant self-reports for a period of the prior 12 months and were obtained as a part of a comprehensive laboratory test protocol. Musculoskeletal injury data were one component of a comprehensive human performance research data collection consisting of biomechanical, musculoskeletal strength and flexibility, balance, physiological, and nutrition variables.[2]

Self-reported musculoskeletal injury data were collected on 106 male USASOC Special Forces Soldiers (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 to 60 years (inclusive); had no recent (3 month) history of traumatic brain injury, 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. All subjects included in this analyses were enrolled as part of our larger research study with USASOC. Since assessment in the overall study requires laboratory testing that involves maximal physical exertion it was necessary that all subjects be free of musculoskeletal injuries in the 3 months prior to ensure prior musculoskeletal injury did not have any residual impact on the laboratory testing procedures. The total duration of injury query was based on 12 months before the laboratory data collection (3 months injury free buffer and 9 additional months).

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 sublocation, 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 PT for a minimum of 1 day, regardless if medical attention was sought. If the injury occurred before enlistment, then the injury resulted in alteration in activities of daily living and/or training/athletic activities for greater than 1 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).

Injuries were then further classified as preventable or not preventable. "Preventable injuries" are those musculoskeletal injuries that can be reduced through injury prevention programs that are developed to improve neuromuscular and physiological characteristics related to risk of musculoskeletal injury. Examples of preventable musculoskeletal injuries include lower extremity stress fractures resulting from running and/or marching and noncontact knee ligament injuries. "Not preventable injuries" are musculoskeletal injuries not able to be deterred through these injury prevention programs and includes injuries such as those sustained during motor vehicle accidents, direct contact, or stepping in a ditch. Other not preventable injuries include certain fractures, such as those to the face, fingers, or toes. The operational definitions of preventable and not preventable musculoskeletal injuries in this study are specific to our research group whose aim is to develop PT programs that improve modifiable neuromuscular and physiological characteristics related to risk of musculoskeletal injury. Although some of the injuries classified in this study as not preventable may be prevented through other intervention strategies, such as sleep modification, these injuries would not be preventable through PT programs.

Statistical Analysis

Self-reported injury data during a period of 1 year before 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 1-year period before data collection have been described. The 106 subjects included in the analysis reported 26 injuries, including 20 preventable injuries, during a 1-year period.

Eighty-four subjects (84/106, 79.2%) did not report any injury during a 1-year period. Eighteen subjects (18/106, 17.0%) reported one injury, and four subjects (4/106, 3.8%) reported two injuries during a 1-year period. Eighty-nine subjects (89/106, 84.0%) did not report any preventable injury during a 1-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 1-year period.

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

The anatomic location and sublocation of injuries are described in Figure 1 and Table I. The lower extremity was the most common location for injuries (13/26, 50.0%) and for preventable injuries (12/20, 60.0%). The shoulder and knee were common sublocations for injuries (each 6/26, 23.1%) and preventable injuries (each 5/20, 25.0%).

Data regarding the cause of injuries are described in Table II. 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.

Data about activity when injury occurred are described in Table III and Figure 2. 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%).

Injury types are described in Table IV. 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%).

Musculoskeletal injuries were classified according to their onset as acute (18/26, 69.2% of injuries), overuse (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 overuse. Musculoskeletal injuries were classified according to their mechanism as contact injuries (10/26, 38.5% of injuries), noncontact 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 noncontact injuries, and one injury (1/20, 5.0%) had an unknown mechanism.

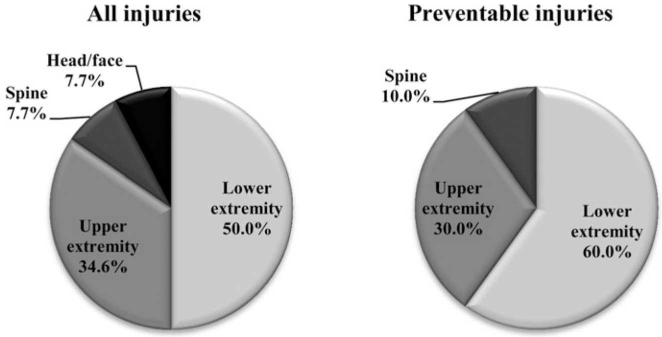

FIGURE 1. Anatomic location of injuries during a 1-year period.

TABLE I. Anatomic Sublocation of the Injuries During a 1-Year Period

Injury Anatomic Location	Anatomic Sublocation	All Injuries *N* (%)	Preventable Injuries *N* (%)
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

TABLE II. Cause of Injuries During a 1-Year Period

Cause of Injury	All Injuries *N* (%)	Preventable Injuries *N* (%)
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

TABLE III. Activity When Injury Occurred During a 1-Year Period

Activity	All Injuries *N* (%)	Preventable Injuries *N* (%)
Combat	1 (3.8%)	0 (0.0%)
Motor Vehicle Accident	1 (3.8%)	0 (0.0%)
PT[a]—Command Organized	12 (46.2%)	12 (60.0%)
PT[a]—Non Command Organized	2 (7.7%)	2 (10.0%)
PT[a]—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

[a]Denotes further classifications of PT as activity when injury occurred.

Musculoskeletal injury data were classified according to type of treatment sought following injury. Eleven injuries (11/26, 42.3%) required some type of diagnostic testing (magnetic resonance imaging, X-Ray or computed tomography scan). Ten injuries (10/26, 38.5%) required rehabilitation, 6 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,

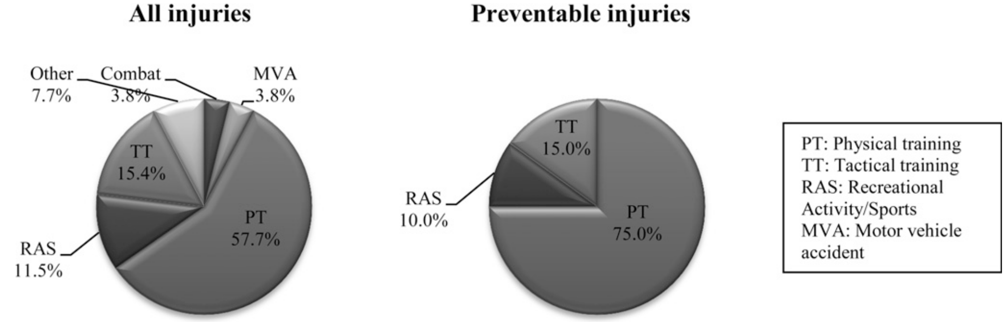

FIGURE 2. Activity when injury occurred during a 1-year period.

TABLE IV. Injury Type During a 1-Year Period

Injury Type	All Injuries *N* (%)	Preventable Injuries *N* (%)
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

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

The objective of this analysis was to describe the self-reported injury epidemiology of 3SFG Soldiers for 1 year before 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 U.S. Army SOF community. When compared with other SOF community, injury frequency and incidence rates are comparable and much less than those in the SOF trainees. Overall, a majority of musculoskeletal injuries occurred during PT and tactical training: they are preventable in nature. It implies that potential prevention strategies should focus on modifying PT and tactical training, especially involving running, lifting, cutting, and landing movements.

Injury Frequency and Incidence

In this investigation, the frequency of all musculoskeletal injury and injury incidence was 24.5 injuries per 100 subjects per year and 20.8 injured subjects per 100 subjects per year, respectively. The injury frequency is comparable with the injury frequency sustained by NSW personnel (approximately 11 to 38 injuries per 100 subjects per year).[8] A study by Linenger et al[11] conducted among U.S. Navy Sea-Air-Land (SEAL) trainees described medical conditions and musculoskeletal injuries during the SEAL candidacy training: This study revealed 29.7 cases of musculoskeletal injuries per 100 trainee-months (approximately 300 injuries per 100 subjects per year), which is higher than the injury frequency in this study. A higher injury frequency (approximately 47 injuries per 100 subjects per year) was also reported by Hollingsworth[7] in Marine Corps Special Warfare personnel during a strenuous predeployment training cycle. There are potential explanations among studies: training phase, injury definition, and subject selection.

In both the Linenger et al[11] and Hollingsworth[7] 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 this study, there was individual variability among subjects in phase of physical and tactical training depending on their missions in upcoming deployments.

In addition, definitions of injury are different among studies. For example, in the study by Hollingsworth,[7] subjects were asked about pain or physical limitation because of musculoskeletal injury during the predeployment 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 1 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 this study.

This 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. Likely, those who suffer musculoskeletal injuries that are severe enough might have been assigned to different units or services outside of the Special Forces community. That would likely mean that we tested some of the most resilient Operators who have been through many training, missions, and/or deployments without major injuries. Again, this would result in underestimation of actual injury counts.

Lauder et al[12] used data in a database for Army personnel in 1989–1994 to describe injuries related to sports and PT. 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 this 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: U.S. Army 101st Airborne Division (Air Assault) and NSW personnel.[2,9] These studies revealed a high incidence of musculoskeletal injuries among 101st Division Soldiers and NSW personnel. In addition to injury frequency and incidence of musculoskeletal injuries, this study separated preventable and nonpreventable injuries. Preventable musculoskeletal injuries comprise the majority of injuries. These results substantiate efforts to reduce injuries through well-designed PT and combat training.

Anatomic Location and Sublocation

Comparison of the anatomic location and sublocation for injuries in this study to those reported in other literature is presented in Table V. In this study, injuries occurred most frequently in the lower extremity in the 3SFG. These data were consistent with Hollingsworth[7] who reported that the lower extremity was the most injured region in Marine Corps Forces Special Operations personnel and with Peterson et al[8] who identified a similar proportion of lower extremity injuries in NSW personnel. In contrast, Lynch and Pallis[6] reported a lesser percent of injuries to the lower extremity in 5SFG. The primary anatomic sublocations of injury identified in this study were the knee and shoulder followed by the ankle. Hollingsworth[7] also identified the knee as the most commonly injured body region followed by the low back and ankle. Contrary to these findings, Peterson et al[8] and Lynch and Pallis[6] reported that neck/back pain was the most common musculoskeletal in NSW personnel and the 5SFG, respectively. Both of these studies also reported the other frequently injured sublocations of injury as the ankle, shoulder, and knee; however, these sublocations were not in the same order.

Musculoskeletal injuries in NSW personnel also were described by our group.[9] We described medical chart–reviewed as well as self-reported injuries. For medical chart–reviewed injuries, the anatomic location most frequently reported was the upper extremity followed by the lower extremity, spine, and torso. For self-reported injuries, anatomic location most frequently reported was the lower extremity followed by the upper extremity, spine, torso, and head/face. The most common anatomic sublocation for medical chart–reviewed injuries was the shoulder and for self-reported injuries was the ankle and shoulder (each 16.7%). The injury distributions revealed in this study of 3SFG more closely resemble the self-reported data collected in the NSW study, with the highest proportion of self-reported injuries occurring in the lower extremity in both cases.

The results of this study of 3SFG are variable in comparison with investigations of injury location in other Army populations. Our research group conducted a study describing self-reported injuries among Army Soldiers in the 101st Airborne Division.[2] Bilateral injuries were counted twice in this report. The majority of injuries (62.6%) affected the lower extremity, which agrees with this study findings among 3SFG, where the majority of injuries (50.0%) also affected the lower extremity. In the study by Lauder et al,[12] the most commonly injured body parts were the knee and the ankle, with anterior cruciate ligament injury most common injury type in men. Although the most common anatomic location is similar to that in this study, shoulder injuries were the most common injury in the current study. The 3SFG Operators participate in more tactical training involving the upper extremity such as marksmanship training, rope climbing/repelling, lifting/loading/unloading, close-quarter combat with or without weapons, and skydiving training. Intensity and frequency of those training are likely related to more shoulder injuries when compared to the general forces.[12]

Types of Injuries and Acute/Overuse

In this investigation, sprain was the most common injury type (23.1%), followed by fracture and strain (each 11.5%). 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 this 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 this study). The results from these investigations reveal consistent injury types. It is also related to how injuries occur. As discussed in the next paragraph, acute injuries are more common than overuse injuries.

The majority of musculoskeletal injuries in this 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[12] 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 overuse injuries. In the study by Linenger et al[11] of Navy SEAL trainees, overuse injuries accounted for >90% of all injuries, but in this study, acute injuries were more common. The fact that study by Linenger et al[11] was conducted among trainees may explain the higher frequency of injuries as well as a greater proportion of overuse injuries, as compared to this study that was not among trainees. The lower extremity was the most common location for injuries in both studies. This is important to note that the 3SFG Operators have been likely managing their training volume and rest cycles to avoid overuse musculoskeletal injuries. Given their age and years of service, the Operators learn the deployment cycles and specific training within each cycle.

Activities and Mechanisms of Injuries When Injuries Occurred

Military injury epidemiology studies have demonstrated that PT is a common activity during which musculoskeletal injuries frequency occur. This investigation revealed that of the injuries classified as preventable, 75% injuries occurred during PT (command organized, noncommand organized, or unknown). In our investigation of injuries in NSW 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 group investigated mechanism of injury in a group of 101st Airborne Division (Air Assault) Solders.[2] Like this study of 3FGS, this study found that training (PT, tactical training, or unspecified training) 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 this study).

Our findings conflict with previous work by Lauder et al,[12] who described only injuries related to sports and PT 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 PT. In contrast, this 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 this 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 et al as compared to this study.

Limitations and Other Considerations

This 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. This investigation and the Hollingsworth study[7] utilized self-reported survey, whereas Lynch and Pallis[6] and Peterson et al[8] utilized diagnostic categories (ICD-9CM) and medical record database. Understanding the differences between medical chart reviews and self-reports, and limitations of each collection method should be recognized.

CONCLUSION

PT 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. Specifically, based on this investigation, reducing acute sprain/strain injuries during running, lifting, cutting, and landing during the centralized PT and tactical training should be focused through proper technique and training intensity/duration.

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Residual Impact of Previous Injury on Musculoskeletal Characteristics in Special Forces Soldiers

Shawn F. Kane, FACSM, John P. Abt, Julie Kresta, James Bakey, Jeffrey J. Parr, Timothy C. Sell, Scott M. Lephart, FACSM
University of Pittsburgh, Pittsburgh, PA, US Army Special Operations Command, Fort Bragg, NC

Musculoskeletal injuries are a significant burden to US Army Special Operations Command (USASOC). The advanced tactical skill level and physical training required of USASOC Special Forces Soldiers highlight the need to improve suboptimal musculoskeletal characteristics, particularly following injury to reduce the likelihood of suffering a recurrent preventable injury. **PURPOSE:** To identify the residual impact of previous injury on musculoskeletal characteristics. **METHODS:** A total of 106 Special Forces Soldiers were enrolled in this study. Isokinetic strength of the knee, shoulder, and back and flexibility of the shoulder and hamstrings were assessed as part of a comprehensive human performance protocol. A self-reported musculoskeletal injury history was obtained from the time of enlistment to that of laboratory testing. Subjects were stratified based on knee, shoulder, or back injury and analyzed separately. **RESULTS:** For the knee injury analysis, no significant strength or flexibility differences existed ($p > 0.05$). For the shoulder injury analysis, 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. 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°, $p = 0.008$). For the back injury analysis, no significant strength differences were demonstrated between the healthy and injured groups ($p > 0.05$). **CONCLUSION:** Few physical differences existed between Soldiers with prior knee or back injury suggesting restoration of strength and flexibility. For differences that existed in the shoulder, rehabilitation/human performance training should target specific suboptimal musculoskeletal characteristics to prevent the recurrence of injury and allow return to unrestricted training and operations.

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. Supported by USAMRMC #W81XWH-11-2-0020

Identification of Asymmetrical and Suboptimal Agonist/Antagonist Strength in a Cohort of Special Forces Soldiers

John P. Abt, Shawn Eagle, Julie Y. Kresta, James F. Bakey, Timothy C. Sell, Shawn F. Kane, FACSM, Scott M. Lephart, FACSM
University of Pittsburgh, Pittsburgh, PA, US Army Special Operations Command, Fort Bragg, NC

Unilateral strength training has gained significant interest within the military as an adopted training principle. Theoretically, unilateral strength training should promote similar bilateral and unilateral agonist/antagonist synergy by limiting the dominant limb's support of total workload. **PURPOSE:** To identify asymmetrical and non-synergistic strength in a cohort of Special Forces Soldiers. **METHODS:** A total of 86 Special Forces Soldiers participated. Isokinetic strength of the knee and shoulder was assessed as part of a comprehensive human performance protocol. The proportion of individual bilateral differences (> 10% difference) was calculated for each joint and variable. The proportion of insufficient strength ratios was calculated based on established normative clinical data. **RESULTS:** Individual bilateral strength differences were identified in 45.1% of subjects for knee flexion and 43.1% for knee extension. An insufficient knee flexion/extension ratio was identified in 43.1% of Soldiers. Individual bilateral strength differences were identified in 45.3% of subjects for internal rotation and 35.8% for external rotation. Insufficient external rotation/internal rotation strength ratios were identified in 35.8-49.1% of Soldiers. **CONCLUSION:** A high proportion of Soldiers demonstrated bilateral asymmetry > 10%. This threshold has been previously identified as a risk factor for musculoskeletal injury and may compromise physical readiness. Soldiers presenting with musculoskeletal asymmetries and/or insufficient strength ratios may be predisposed to musculoskeletal injury. Both of these scenarios may limit physical readiness at the individual and unit level. Individuals demonstrating asymmetrical or insufficient strength ratios may benefit from unilateral strength training.

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Dietary Protein Intake and Protein Supplement Use of United States Army Special Operations Command Operators

Rachel A. Baker, Kim Beals, Matthew E. Darnell, John P. Abt, Timothy C. Sell, Shawn F. Kane, Jeffrey S. Morgan, Peter J. Benson, Scott M. Lephart,

University of Pittsburgh, Pittsburgh, PA, US Army Special Operations Command, Fort Bragg, NC

The desire to gain lean muscle mass is a common body composition goal of United States Army Special Operations Command (USASOC) Operators. Sports nutrition guidelines recommend dietary protein intake of 1.2-1.7g/kg/day for resistance-trained athletes. In accordance with the Department of Defense's Operation Supplement Safety campaign, Dietitian's advocate Operators take a "food first" approach instead of using dietary supplements. **PURPOSE:** To assess the number of USASOC Operators taking protein supplements and whether or not protein needs are met through diet alone. **METHODS:** A total of 91 USASOC Operators (age: 29.1±6.5yrs, height: 70.5±2.8cm, weight: 81.4±9.7kg, body fat: 15.9±5.3%) completed a 24-hr dietary recall and nutrition history questionnaire. Dietary intake was analyzed using an automated self-administered 24-hour diet recall. **RESULTS:** Protein intake was 137±59g/day. Protein requirements were met or exceeded through diet alone in 79% of Operators, of these, 42% reported protein supplement use. Dietary protein recommendations were not met in 21% of Operators, of these 42% indicated taking a protein supplement. **CONCLUSION:** The majority of USASOC Operators are consuming adequate dietary protein to promote lean muscle gains with strength-training. Exceeding the recommended range for protein, has not been shown to promote further gains in muscle size/strength, and may lead to undesirable weight gain if caloric needs are surpassed. Consuming protein supplements raises safety concerns, potentially exposing Operators to harmful ingredients in unknown amounts. Nutrition education focused on high quality protein foods properly timed throughout the day may decrease reliance on protein supplements and provide a safer alternative. Supported by ONR # W81XWH-11-2-0020.