Sex Comparison of Physical and Physiological Changes in Characteristics During Marines Ground Combat Military Occupational Specialty Training

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The rescindment of the Direct Ground Combat Assignment Rule allowed women to serve in all Military Occupational Specialty (MOS) assignments. The Ground Combat Element Integrated Task Force (GCE ITF) was established to train female Marines in ground combat MOS skills and assess how sex integration of ground combat units impacts tactical performance. Examining the changes in physical and physiological characteristics of women during integration is essential. **PURPOSE:** To observe and investigate how physical and physiological characteristics of both men and women change during ground combat MOS training. **METHODS:** 60 Marines (24 women, height=160.08 ± 20.85 cm, weight=66.32 ± 6.19 kg; and 36 men, height=178.51 ± 6.38 cm, weight=78.48 ± 10.57 kg) completed testing during pre-ITF and post-ITF time points. Body composition was collected via air displacement plethysmography; trunk, shoulder, and knee strength were collected with an isokinetic dynamometer; aerobic fitness and lactate threshold was assessed with a metabolic unit and lactate analyzer; and anaerobic fitness was collected with an electromagnetically braked cycle ergometer. Results were analyzed with a two-way measure analysis of variance. **RESULTS:** A main effect of time ($p<0.05$) was found for the following variables: body fat percentage, trunk flexion and extension strength, right and left shoulder internal rotation strength, left knee flexion strength, and right knee extension strength. A main effect of sex ($p<0.05$) was found for the following variables: body fat percentage, trunk flexion and extension strength, right and left shoulder internal rotation strength, right shoulder external rotation strength, right and left knee flexion and extension strength, VO_2 max, lactate threshold, and anaerobic capacity. **CONCLUSION:** The results of this study suggested that male Marines tended to be stronger than female Marines, had better aerobic and anaerobic fitness, and less body fat. Additionally, many of the variables tested showed a reduction from pre- to post-ITF training and assessment. The results of this study provided evidence that there are sex differences in body composition, strength, and physiological fitness after ITF training and assessment phases in Marines.

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Preface

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1.0 Introduction

The United States Marine Corps was established on November 10, 1775, when a resolution was passed stating that "two Battalions of Marines be raised" for service as landing forces with the fleet. The first recruiting headquarters was set up in Philadelphia, Pennsylvania by Captain Samuel Nicholas who said he was looking for "a few good men".[1] By 1798, there were a total of 83 Marines to be accounted for and that number has exponentially grown since. By 2018 it was recorded that there were 21,454 officers and 164,376 enlisted Marines in the corp.[2]

Each Marine is trained to improvise, adapt, and overcome all obstacles in any given situation; however, this branch of the Military is comprised of specific roles available for highly specialized Marines.[1] These roles are known as Military occupational specialties, or MOSs, and require advanced formal training in order to become a specialized field expert. Some examples of these roles include infantry, mountain warfare, artillery, and combat engineers.

To become a basically trained Marine, all Marines must attend Recruit Training and either Officer Candidates School or entry level training. Marines with an infantry MOS will attend the Infantry Training Battalion for a 59-day course that will focus on training to be proficient in rifleman fundamentals. Any Marine with a non-infantry MOS is trained at the Marine Combat Training Battalion, which is a 29-day course focusing on ensuring every Marine is a fighting Marine. Those who attend Officer Candidates School will attend Basic School to further develop leadership skills before finally attending Specialized Officer Training to become an expert in their MOS.[3]

1.1 Integration of Women

Post-World War II, more women began to express interest in serving in the Military, but at that time there were still very traditional views held regarding the role women should have in society. There were multiple oppositions to involving women in the military such as the view that "women should be protected from harm" and "women should not kill". Additionally, there was a concern that if women were sent into combat positions, the American public would be a reluctant to support the use of military force in the future. It wasn't until the Women's Armed Services Integration Act of 1948 that women were authorized to enlist in the Army, Air Force, Navy, and Marine Corps alongside men.[4]

1.1.1 A Change of Policies

Regardless of women being integrated into the armed forces, the Direct Ground Combat Exclusion Rule of 1948 limited the opportunity for women to serve in only non-combat roles after Congress determined it necessary to shield servicewomen from the risks of enemy fire and capture. In 1994, the Secretary of Defense wanted to expand opportunities for women, so he established the Direct Ground Combat Assignment Rule. The policy reads: *"Service members are eligible to be assigned to all positions for which they are qualified, except that women shall be excluded from assignment to units below the brigade level whose primary mission is to engage in direct combat on the ground".*[5] In February of 2012, the 1994 rule was modified and opened over 14,000 positions that were previously closed to women, but it wasn't until January of 2013 that this ban was completely lifted by the then-Secretary of Defense, Leon Panetta, allowing women to finally serve in all MOS assignments.[6] Panetta tasked each branch of the armed forces with validating occupational performance standards for all military occupational specialties to ensure eligibility for each field consist of qualitative and quantifiable standards.[7]

1.1.2 Ground Combat Element Integrated Task Force

Although this is a progressive step forward, there are key issues that needed to be considered for the integration of women to be successful. One of the most vital issues being setting standards that ensure members are proficient in the abilities needed to succeed while still ensuring accessibility to women.[7] To understand this, the Commandant of the Marine Corps authorized the formation of a Ground Combat Element Integrated Task Force (GCE-ITF). The purpose of this task force was to train female Marine volunteers in MOS skills and integrate them into a combat unit. Meanwhile, the unit's performance would be observed in an operation environment to evaluate the execution of individual and collective tasks. The main objectives would be to establish sex neutral occupational standards and estimate the effect of sex integration in combat MOSs.[8]

Sex-neutral occupational standard refers to the idea that all members of the Military who are serving in a military career designator must meet the same performance outcome-based standards. This standard is based entirely on physical capabilities required for the specific job and are the exact same for men and women. It's also important to mention that these standards should not screen out a higher proportion of one sex who are able to perform the necessary responsibilities.[9]

Developing physical standards is imperative in the selection process when determining whether an applicant can meet the demands of a particular specialty. Six stages have been established to appropriately determine these standards (refer to Figure 1).

The first steps involve accurately identifying the tasks and responsibilities that a job requires so that screening tests can then be determined to evaluate individuals on their ability to do that task sufficiently. Once established, these tests need to be validated to provide evidence that the test can be used to accurately predict the claim(s) it intends to measure. The next step would be to identify cut off scores that will be used as the minimum score required to be considered "competent" in that task. The last two steps are to implement the screening and confirm the tests are working as intended.[9]

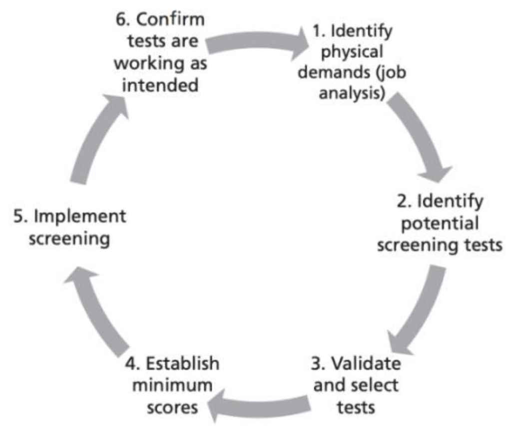

Figure 1. Developing Physical Standards

1.2 Task and Demand Analysis

Prior to developing standards, common movement patterns of the tasks and responsibilities of Marines in various MOS assignments must be recognized. For example, Marines in infantry need to be able to perform pack mounting and a 7-kilometer hike followed by digging. Pack mounting requires a lower extremity squat with the pack on their knee and bilateral shoulder flexion and external rotation to lift and flip their 114-pound pack over their head as they stand.

Additionally, digging requires repetitive lumbar and hip flexion and extension. Based off these movement patterns, potential screening tests may want to look at aerobic fitness, as well as knee, shoulder, and core strength.[10]

Marines in mountain warfare need to be able to perform a 9.5-kilometer hike with a weighted pack. Obviously, this type of long, strenuous activity would require high aerobic capacity. They then perform gorge crossing and rock climbing, which would also indicate needing a test for knee flexion and extension, shoulder internal and external rotation, and torso flexion and extension. On the other hand, artillery would require Marines to fire a 95-pound howitzer round. This type of activity would require short bursts of high intensity movements and therefore, anaerobic power and capacity would be a good measurement to record.[10]

Based off these observations, body composition, strength, and physiological characteristics will be the focus of this paper.

1.3 Body Composition

Body composition can play a large role in one's ability to successfully perform different tasks. Even athletes who compete in different sports have vastly different physical appearances that allow them to optimize their training. An example can be seen in marathon runners who tend to have less body fat whereas other athletes might participate in a sport where a larger body size can be advantageous, such as football or basketball.[11] The importance of body composition as it relates to performance is no different for tactical athletes. In fact, since tactical athletes tend to perform tasks in combat gear which increases weight of load carriage, less body fat and more fat-free mass would benefit performance in combat.[12]

1.3.1 BMI

Body mass index (BMI) is a measure of body fat based on a person's height and weight. While it can be a useful tool for assessing body composition and overall health, BMI can also be used to evaluate physical performance in certain occupations, including the military. The military requires high levels of physical fitness and endurance, such as the ability to carry heavy loads, run, jump, and climb. In addition to soldiers being expected to be able to engage in physically demanding tasks, physical fitness is also important for the safety of soldiers and the success of their missions. Thus, BMI is one of the factors that is considered in the solder selection process. If body fat for men and women falls outside selected ranges, the soldier may have to engage in remedial training and weight loss, or even be dismissed from the military altogether.[13]

Pierce et al. recruited over 300 male and female soldiers to assess how BMI affects physical performance as well as military-relevant tasks. The results showed that those with a higher BMI showed improvements in muscular strength and power, but also had a decreased speed during the 2-mile run. Although there is a tradeoff, this study supports that increased BMI can negatively affect some aspects of performance.[14]

Another study concluded similar results, finding a strong association between cardiorespiratory fitness and body composition in Brazilian Military firefighters. Cardiorespiratory fitness was measured by the 12-minute Cooper test, a test in which participants are instructed to run as far as they can within 12 minutes. Cardiorespiratory fitness was lower in participants categorized as obese, as classified by BMI cutoff ranges, showing that performance is negatively associated with BMI.[15]

Apart from performance, body mass index is important as it relates to injury risk. In a study using soldiers entering Army basic training, the relationship of BMI to injury risk was bimodal for both men and women. Those with the lowest and highest BMIs were at the highest risk of injury, while those with an average BMI were found to have the lowest risk of injury.[16] This may be explained by either the excess weight putting a strain on the body or because a high BMI could be an indicator of poor health. On the other hand, a low BMI could be an indicator of poor nutrition or other health concerns.

1.3.2 Body Fat Percentage

Body weight may not the best measure for assessing changes in body composition because it is possible that increases in body mass may be due to increases in muscle mass rather than fat mass. Therefore, a better measurement to assess body composition is body fat percentage (BF) or fat-free mass (FFM) which can be obtained from techniques such as bioelectrical impedance analysis, dual energy x-ray absorptiometry (DEXA), or air displacement plethysmography (BOD-POD).[17] This is evident in a study published in 2023 that investigated the association between body mass and percent body fat and performance on the combat fitness test in Marines. BOD-POD data was used to obtain body mass and body fat percentage for both men and women. The researchers found that a significant relationship existed between body fat percentage and combat fitness test performance. Marines with less body fat performed better than those with a higher percentage of body fat, whereas there was no significant difference found between body mass and performance.[18]

In a related manner, another study found that women with increased body fat percentage performed worse in combat-related tasks.[19] A study conducted in 2011 found that Soldiers with similar fat-free mass, but less than 18% body fat performed significantly better on fitness tests, had improved aerobic and anaerobic capacity, and increased muscular strength compared to Soldiers with more than 18% body fat.[20] Additionally, body fat has been suggested to be associated with injury risk. Low body fat percentage was associated with higher risk of stress fractures in Army basic combat training recruits.[21]

1.4 Strength

Muscular strength is one of the five components of physical fitness which emphasizes the importance strength has on health. An increase in strength has been correlated with improved coordination and balance, as well as increases in flexibility and mobility.[22] There are multiple ways that maximal strength can be increased including resistance training which has been shown to improve body composition, power production, and occupational task performance. [23]

The effects of strength training on simulated Military task performance in soldiers was observed in a study published in 2020. The participants were separated into three groups (a soldier task specific training group, a strength group, and a control group) and were tested before, during, and after a 12-week training intervention. The Military task performance consisted of Army soldier tasks including sprints, crawling, carrying objects, and casualty evacuation, while the strength group focused on squats, hamstring curls, pull and push exercises, and core training. The study found that the task-specific group and the strength training group were effective in improving performance in the simulated military task course.[24]

1.4.1 Core

The core is responsible for stability, balance, and overall physical endurance,[25] all of which are critical for physical demands of military training and operations. For example, a strong core may allow a soldier to maintain proper posture while carrying heavy loads, or it might improve balance for soldiers navigating difficult terrain.

Core stability and core strength can have ambiguous definitions, but they generally refer to different things. Core stability is the integration of the passive spinal column, active spinal muscles, and the neural control unit, as described by Panjabi.[26] Faries and Greenwood describe core strength as the ability of the musculature to produce force through contractile forces and intra-abdominal pressure.[27] It is important to have sufficient stability and strength in order for the body to function in daily life, but it has also been suggested that with sufficient stability and strength, athletic performance could be enhanced.[28] The idea behind this is maintained by the understanding that core stability and strength lead to a greater maximal power and more efficient use of the shoulder, arms, and legs which then leads to a lower risk of injury, as well as has a positive effect on power, speed, and aerobic endurance.[29] Similarly, prior research shows core strength has a direct relationship with the ability to create and transfer forces to the extremities, allowing for an overall increase in ability to perform.[30]

A randomized controlled study recruited healthy military members to participate in 12 weeks of basic training. Half of the members were assigned to a core group that underwent extra core muscle functional training, while the control group had no extra training. After the 12-week training, 10.8% of recruits who performed the extra core training experienced lower back pain, whereas in the control group, the incidence of lower back pain was up to 20.8%. The study concluded that the core muscle functional training was effective in reducing the incidence of lower back pain, as well as showed improvement in lumbar muscle endurance and relieved lumbar dysfunction in military recruits.[31]

1.4.2 Upper Extremity

Upper extremity strength is another important component of overall physical fitness, and it plays a crucial role in military performance. Marines must be able to carry heavy equipment over long distances or periods of time, as well as perform overhead movements. Poploski et al. explored the associations of shoulder strength and performance in 195 male Marine Corps Forces Special Operations Command personnel. Shoulder internal and external rotational strength were assessed using an isokinetic dynamometer and performance was measured using explosive push-ups. The researchers found that increases in shoulder strength did translate to functional performance, but overall performance could be limited by the weaker shoulder.[32]

As previously mentioned, soldiers engage in many physically demanding activities including carrying heavy equipment and performing exercises that require a substantial amount of upper body strength. Because of this, Military personnel are very susceptible to injuries stemming from instability and mobility of the shoulder joint.[33] A study in 2017 looked to further explore any physical and performance characteristics that may predict musculoskeletal injuries, and they found that weakened shoulder strength was a risk factor for injury. Specifically, it was noted that those in the bottom 25th percentile of shoulder retraction strength were almost five times more likely to sustain an injury.[34] Another possible risk factor for injury in this population is side-to-side strength imbalance. A study investigated by Eagle et al. wanted to compare the odds of reporting previous shoulder injuries in the Marines based on the difference in magnitude of shoulder rotator bilateral strength. They found that Marines with larger magnitude internal rotation strength differences demonstrated increased odds of reporting a previous shoulder injury, but also female sex increased those odds when compared to males.[35]

1.4.3 Lower Extremity

Similarly, lower extremity strength is also an important aspect of physical fitness in the Military. Not only is lower extremity strength essential for running and other types of aerobic activities, but it may also play a role in performance pertaining to tasks that require a high level of lower body strength such as squats and lunges. Lower extremity strength may even play a role in predicting ground combat military occupational school graduation, as concluded by a study published in 2017 which focused on predictive characteristics in female Marines. They found that absolute and normalized ankle inversion and eversion strength significantly predicted MOS school graduation and recommended future female Marines to train to optimize these characteristics.[36]

It is not uncommon to find increased knee pain caused by the functional tasks required for Military personnel, especially early in Military careers. From 2006 to 2015, 151,263 enlisted members across all Military branches were diagnosed with anterior knee pain. Researchers found that both sex and Military occupation were the salient factors for risk of knee pain.[37] In addition, it is understood that quadricep asymmetry is associated with lower extremity injuries in tactical populations. Of 150 operators, those who demonstrated larger strength differences in bilateral knee extensions were more likely to report a knee injury.[38] It is imperative to reduce the incidence of knee pain and the best way to do that may be to implement strength and rehabilitation training which focus on correcting strength imbalances.[36]

1.5 Physiological Characteristics

1.5.1 Aerobic Fitness

Both aerobic and anerobic fitness are important in the Military so soldiers can perform a variety of endurance exercises, including running, marching, swimming, or completing a ruck. Aerobic fitness can be described by aerobic power, or the maximal rate at which oxygen can be used during heavy or intense exercise. Someone with higher aerobic power would be able to endure heavy physical activity over a longer period of time because they have more oxygen being transported to their muscles.[39] Aerobic capacity supplies energy for low intensity exercises over long durations and is vital for faster recovery.[40]

There are a multitude of factors that can influence aerobic power and one of those factors could be load carriage. A study involving 12 special weapons and tactics operators focused on how the need to carry heavy equipment during Military operations may affects tactical performance. The operators were timed during a simulated tactical test while carrying heavy loads and without carrying heavy loads. It is not surprising that they were able to complete the simulated quicker without the load than with the load. The decrease in performance was due to the increase of workload which indicates that greater aerobic power could help reduce the negative effects of loads carriage on task efficiency.[41]

Interestingly, previous studies have suggested that women may have reduced aerobic fitness when compared to men due to them carrying less fat-free mass, a greater amount of adipose tissue, lower oxygen carrying capacity, and a decreased cardiac output.[42] A cohort study recruited 143,398 men and 41,727 women to investigate how aerobic fitness related to injury risk. Results showed that as their 2-mile run times increased, injury risks increased as well.[16] A meta-analysis of 21 studies measuring aerobic fitness found that there is a significant increase in risk of injury of training personnel who perform in the bottom quartile when compared to those in the fastest quartile.[43]

1.5.2 Anaerobic Fitness

Anaerobic power and capacity have been found to be reflective of the ability to perform quick bursts of activity. The word anaerobic means “capable of living in the absence of oxygen”, so when related to exercise, anaerobic refers to the ability to synthesize adenosine triphosphate without the use of oxygen.[44] This metabolic process plays a big role in muscular strength and power, two characteristics that are needed in many MOS assignments.

Muscular endurance is thought to be improved by increasing anaerobic fitness that focuses on high-intensity, short-duration activities. Bishop et al. showed the importance of upper and lower body anaerobic power has for military training, specifically during obstacle courses. [45] Moreover, anaerobic power was also considered an important characteristic to reduce fatigue and the negative effects of load carriage on task efficiency in the study consisting of special weapons and tactics operators.[41] Another Military research study assessed the anaerobic power capacity of 34 infantrymen before and after a five-day combat scenario. Results from this study suggested that anaerobic power capacity may play a role in the ability to sustain infantry tasks over a period of time.[46]

1.6 Definition of the Problem

Specific training for each of the numerous Military Occupational Specialties (MOS) is required of all Marines. After rescinding the Direct Ground Combat Assignment Rule women were able to participate in these trainings for the first time, but there was a lack of research and information regarding the optimization of training and prevention of injuries for women in individual MOS's. Furthermore, it was unclear how women would physically adapt over the course of their training. This research should assist with identifying changes in physical and physiological characteristics during Military training in effort to improve performance and reduce injury.

1.7 Purpose

The purpose of this study is to observe and investigate how physical and physiological characteristics of both men and women change during MOS training.

1.8 Specific Aims and Hypotheses

1.8.1 Aim 1

To compare changes in body composition of men and women after Ground Combat Element training as determined by fat mass percentage.

Hypothesis 1A: Women will show greater changes in fat mass percentage after Ground Combat Element Training when compared to men.

1.8.2 Aim 2

To compare changes in core strength of men and women after Ground Combat Element training as determined by isokinetic trunk extension and flexion strength.

Hypothesis 2A: Women will show greater changes in core strength after Ground Combat Element Training as compared to men.

1.8.3 Aim 3

To compare changes in upper extremity strength of men and women after Ground Combat Element training as determined by shoulder internal and external rotation strength.

Hypothesis 3A: Women will show greater changes in shoulder internal and external rotational strength after Ground Combat Element Training when compared to men.

1.8.4 Aim 4

To compare changes in lower extremity strength of men and women after Ground Combat Element training as determined by isokinetic knee extension and flexion strength.

Hypothesis 4A: Women will show greater changes in knee extension and flexion strength after Ground Combat Element Training when compared to men.

1.8.5 Aim 5

To compare changes in maximal oxygen consumption of men and women after Ground Combat Element training as determined by a maximal treadmill exercise test.

Hypothesis 5A: Women will show greater changes in aerobic fitness after Ground Combat Element Training when compared to men.

1.8.6 Aim 6

To compare changes in anerobic power of men and women after Ground Combat Element training as determined by a Wingate 30-second cycle test.

Hypothesis 6A: Women will show greater changes in anaerobic fitness after Ground Combat Element Training when compared to women.

1.9 Study Significance

After the rescindment of the Direct Ground Combat Assignment Rule, the then-Secretary of Defense, Leon Panetta, tasked the branches of the Military with creating a plan that would allow successful integration of women into combat roles. The Ground Combat Element Integrated Task Force was established to assess the impact of gender integration. Obtaining the results of this study will be important in the optimization of training in the Military and will provide insight into decreasing injury risk factors for both men and women. Much more research is needed to understand how characteristics adapt in females, specifically those in the Marine Corps.

2.0 Methodology

2.1 Experimental Design

Up to 336 men and women aged between 18 and 55 participated in this longitudinal research study. A total of two time points were recorded including a baseline and a post-training time point. Baseline testing, or pre-ground combat element (pre-ITF) testing began as participants consented to the University of Pittsburgh arm of the larger GCE ITF study commissioned by the USMC. Post-ITF testing began in May of 2015.

Each of the time points had an identical collection process beginning with recording basic anthropometrics such as height, weight, and body composition. The participants then performed a series of tests to gather data on their aerobic capacity, their anaerobic power and capacity, and their core strength.

2.2 Subject Recruitment

Male and female Marines who were enrolled as part of the Ground Combat Element Integrated Task Force were recruited during group briefs to participate in the University of Pittsburgh arm of the research study. This took place at the Human Performance Research Laboratory in Camp Lejeune, North Carolina.

2.3 Subject Characteristics

2.3.1 Inclusion Criteria

The inclusion criteria for this study included the following: 1) Marines up to age 55 and 2) are currently cleared for full active-duty participation by the Senior Medical Officer or another designated member of the medical staff.

2.3.2 Exclusion Criteria

The exclusion criteria included the following: 1) subjects with complaints of current symptomology of the extremities, neck, or back that have prevented training within the previous three months, 2) subjects who are allergic to adhesive products, and 3) subjects who are knowingly pregnant. In addition, any subject who develops a disease or condition during the course of the study that prohibits active participation in Marine training will be automatically released from the study.

2.4 Power Analysis

This study was conducted utilizing data from a larger study, GCE-ITF Study. Available data from Marines who participated in the pre-ITF and post-ITF stages of the GCE-ITF study were included in this analysis. This was a convenience sample from the larger study.

2.5 Instrumentation

2.5.1 BOD POD Body Composition Tracking System

Fat and fat-free body mass was obtained using a Bod Pod body composition tracking system (Cosmed, Chicago IL). Body composition has been shown to play a role in performance in Military personnel and is highly reliable (ICC=0.98) and precise (SEM=0.47%BF).[20]

2.5.2 Biodex System 3 Isokinetic Dynamometer

Strength was obtained by measuring trunk and knee flexion and extension, and shoulder internal and external rotation using a Biodex System 3 isokinetic dynamometer (Biodex Medical Systems Inc., Shirley NY). Validity and reliability of this device was ensured in a study that assessed position, torque, and validity.[47] Isokinetic strength testing has been reported as reliable with ICC values ranging from 0.74 to 0.99.[48]

2.5.3 Maximal Oxygen Uptake and Lactate Threshold Collection

Aerobic capacity and lactate threshold were obtained using a TrueOne 2400 Metabolic Unit (ParvoMedics, Sandy UT) and a LactatePro blood lactate test meter (Arkray, Kyoto Japan). Aerobic power can be determined by a maximal treadmill (WOODWAY USA, Inc., Waukesha WI) test to determine maximal oxygen consumption (VO_2max) as well as lactate threshold. A heart rate monitor (Polar USA, Lake Success NY) was also worn by the Marine around the chest at the level of the xyphoid process. This test has been found to be both reliable and valid in measuring aerobic fitness when compared to other maximal tests, such as the 2-mile run and the 20-meter shuttle test.[49]

2.5.4 Velotron Cycling Ergometer

Anaerobic power and capacity were obtained using a Velotron cycling ergometer (RacerMate, Inc., Seattle WA) to perform a 30-second Wingate cycle test. A 2012 study reported that the Wingate test is a valid and reliable measure of anaerobic power and capacity.[50]

2.6 Procedures

2.6.1 Collection of Body Composition

Pre-measurements of body composition were taken using Bod Pod data. To adjust for confounding variables, Marines were required to wear spandex shorts, a sports bra (for females), and a swim cap to cover all hair. Next, Bod Pod was used to obtain body volume by measuring changes in pressure within an enclosed chamber. The Marines were instructed to remove all metal and void their bladder and bowls. Height and weight were recorded, and a two-point calibration was performed by first calibrating with an empty chamber and then calibrating it again with a cylinder with a known volume (50 L). The Marine was asked to sit in the chamber with the door closed and breathe normally. After 40 seconds, the door was opened and subsequently shut, repeating the test for a second time. Testing was completed if the two results did not differ by more than 150 milliliters. At this point, the two scores were averaged and used to calculate body volume and density. Finally, using body density, researchers were able to convert into percent body fat. These methods were repeated using the same procedures at the post-ITF timepoint. Changes in their average body mass (kg) and body fat (%) were collected.

2.6.2 Collection of Core, Shoulder, and Knee Strength

Isokinetic strength testing data was collected using the Biodex Multi-Joint System 3 Pro (Biodex Medical Systems, Inc., Shirley NY) to assess average peak torque to body weight for the trunk, shoulder, and knee. Torque values were automatically adjusted for gravity by the Biodex Advantage Software v3.0 (Biodex Medical Inc., Shirley, NY). Prior to assessment, the Biodex was turned on by turning the switch to the ON position and the dynamometer was automatically calibrated. Before collecting data, a new patient file was created by selecting “add new patient” and filling in their last name, subject ID number, weight in kilograms, gender, and dominant limb, and then indicating the LE being assessed (right or left for UE and LE). After selecting for a unilateral isokinetic protocol, the set-up was adjusted on an individual basis.

Core

Trunk flexion and extension strength were assessed in the semi-standing position using the Biodex trunk flexion/extension attachment. All positioning and stabilization occurred according to manufacturer’s recommendations. The axis of rotation was aligned with the superior edge of the iliac crest, while the foot plate was adjusted to allow the subject’s knees to be at 10–20 degrees of flexion with their posterior thighs supported by the seat of the attachment. Two Velcro straps across the subject’s thighs and two Velcro straps that crossed the subject’s torso were used for stabilization allowing for optimal trunk strength production. All range of motion limits were set based on subject's individual trunk range of motion. For familiarization, everyone was given a practice period of three trials at fifty percent of self-perceived maximum effort followed by three trials at one hundred percent of self-perceived maximum effort. Following a 60-second rest period, each subject performed five reciprocal concentric-concentric trials at one hundred percent of the subject's self-perceived maximum effort.

Shoulder

The Marines were seated and restrained per the manufacturer's guidelines to restrict accessory motion. The shoulder was positioned slightly flexed (approximately 15 degrees) and abducted (approximately 45 degrees) at the neutral starting position. Three warmup trials were completed at 50% of their maximal effort and an additional three at 100% maximal effort followed by a 60-second rest. Five repetitions were done at 60 degrees/second. At the end of this procedure, another trial following the same methods was repeated on the other UE. All values were provided by the general evaluation output.

Knee

First, either a left or right attachment was used dependent on the side being tested, then the seat position was adjusted by rotating the chair to 45 degrees and moving the seatback fore/aft until the participant was in a comfortable, upright seated position with their knees two inches past their chair. The subject was stabilized in the chair by tightening a thigh strap and buckle, and a pelvic strap and buckle. The dynamometers height, tilt, and rotation were adjusted so that the dynamometer was in line with the subject's lateral femoral epicondyle. The knee attachment was adjusted so that it was proximal to the medial malleoli. All positioning measurements were recorded to standardize the testing position for each subject. Following this, starting position of the knee was set and gravity correction was obtained before setting the range of motion. Each subject was familiarized with the protocol before data was acquired. Three practice trials at 50% maximal effort and 3 practice trials at 100% maximal effort were completed prior to testing. There was a rest period of 60 seconds prior to further testing. When ready to begin collecting data, the operator hit “Go” and the participant was asked to extend their LE by pushing as hard and fast as possible and then pulling back into flexion in a similar fashion. This was repeated five times. At the end of this procedure, another trial following the same methods was repeated on the other LE. All values were provided by the general evaluation output.

2.6.3 Collection of Aerobic Capacity and Lactate Threshold

A maximal treadmill exercise test was completed at pre- and post-GCE time points. Prior to beginning the test, each participant was fitted was a mask connected to the metabolic system and a heart rate monitor. An established protocol was used to keep trials consistent. Military members completed a five-minute warm up at a moderate pace, which was a percentage of their pre-determined test speed. The test stage began at 0% grade and increased 2.0% every three minutes while speed was held constant. At the end of each stage, the participants finger was pricked with a needle to provide a drop of blood that was used to determine lactate levels. Subjects were instructed to continue the test until exhaustion (defined as the inability to continue the test due to cardiovascular or peripheral inhibition). Heart rate and maximal oxygen consumption were monitored during the entirety of the test. Variables which were collected include VO_2 max and lactate threshold.

2.6.4 Collection of Anaerobic Power and Capacity

A Wingate test was used to collect anaerobic power and capacity. After a 10-minute warm-up at submaximal speed, participants were instructed to pedal as fast as they can without any resistance for 20 seconds. Then, a fixed resistance was applied to the flywheel and the participant was instructed to continue pedaling as hard as they could for 30 seconds. The fixed resistance was determined to be set at 0.09 kilograms per kilograms of body mass for males and 0.075 kilograms per kilograms of body mass for females. The outcome variables included anaerobic power and anaerobic capacity.

2.7 Data Reduction

In total, 224 males and 112 women participated in the study. Due to time constraints, injuries, and voluntary-withdrawal from the study, only 19 men and 8 women completed all three time-points. For the purposes of this paper, only those who completed both the pre-ITF and post-ITF time points (36 men, 24 women) will be analyzed.

Strength obtained by the Biodex dynamometer was reported as the peak average torque across 5 trials and was normalized to each participant's body mass.

For VO_2 max data, a 15-second moving window was used to filter metabolic data to reduce the overall breath-by-breath data points. Maximal oxygen uptake was calculated as the highest consecutive oxygen uptake levels over 60 seconds of data collection relative to body mass. Lactate threshold was determined by the inflection point when blood lactate levels increased by one mmol/L or more between stages and reported as a percentage of VO_2 max.

Anaerobic power output was identified as the peak power within the first five seconds of the test following resistance initiation. Anaerobic capacity was calculated as the mean power output over the 30 seconds of the test following resistance initiation and was also normalized to body mass.

2.8 Data Analysis

Descriptive statistics (mean, standard deviation, median, IQR, or proportion, as appropriate) will be calculated for all variables.

A two-way mixed measures analysis of variance (ANOVA) was utilized to analyze the effect of sex (female, male) and time-point (pre-ITF, post-ITF), and effect of interaction between the independent variables on the dependent variables. Separate ANOVA's were conducted for each dependent variable. Effect sizes were calculated. Assumptions for the ANOVA were assessed, and data transformations or non-parametric tests were conducted as required.

Statistical significance was set a priori at alpha=0.05, two sided. Data analysis was conducted using SPSS statistics version 28 (IBM Corp; Armonk, NY).

3.0 Results

The purpose of this study was to observe and compare how physical and physiological characteristics of both men and women changed during MOS training. The following sections present the analyzed results of fata collected during the study, including descriptive statistics, statistically significant differences, and effect sizes.

60 Marines (24 women, height=160.08 ± 20.85 cm, weight=66.32 ± 6.19 kg; and 36 men, height=178.51 ± 6.38 cm, weight=78.48 ± 10.57 kg) completed the pre-ITF and post-ITF time points. Mean, median, and standard deviation were recorded for each of the 15 variables tested which can be seen in Table 1.

Table 1. Descriptive Statistics for Body Composition

	Sex	N	Pre			Post		
			Mean	SD	Median	Mean	SD	Median
Body Fat (%)	Female	24	25.22	3.61	25.75	24.12	3.47	24.05
Body Fat (%)	Male	36	17.46	5.66	17.55	16.45	4.50	16.80

Table 2. Descriptive Statistics for Strength

	Sex	N	Pre			Post		
			Mean	SD	Median	Mean	SD	Median
Trunk Flexion Strength (N*m)	Female	23	175.20	25.67	172.93	154.09	20.09	153.04
Trunk Flexion Strength (N*m)	Male	35	210.35	32.10	207.08	190.90	30.64	193.64
Trunk Extension Strength (N*m)	Female	23	263.14	61.94	253.23	227.85	55.03	219.44
Trunk Extension Strength (N*m)	Male	35	335.06	68.33	341.03	317.81	70.56	316.61
Right Shoulder Internal Rotation Strength (N*m)	Female	23	39.73	7.27	40.37	36.01	5.90	36.10
Right Shoulder Internal Rotation Strength (N*m)	Male	36	59.38	15.03	56.27	54.74	14.88	53.60
Left Shoulder Internal Rotation Strength (N*m)	Female	22	38.04	7.63	39.37	35.54	7.57	33.38
Left Shoulder Internal Rotation Strength (N*m)	Male	35	56.76	12.01	54.73	51.39	11.39	50.71
Right Shoulder External Rotation Strength (N*m)	Female	23	30.31	3.55	31.34	29.32	4.18	29.60
Right Shoulder External Rotation Strength (N*m)	Male	36	42.91	8.27	41.54	41.05	6.53	40.44
Left Shoulder External Rotation Strength (N*m)	Female	22	27.76	3.22	27.78	28.65	3.78	29.31
Left Shoulder External Rotation Strength (N*m)	Male	35	39.73	6.54	38.87	36.98	5.24	35.54
Right Knee Flexion Strength (N*m)	Female	23	107.07	16.76	109.46	102.94	18.45	101.40
Right Knee Flexion Strength (N*m)	Male	34	124.18	26.74	124.13	120.43	25.53	124.30
Left Knee Flexion Strength (N*m)	Female	23	105.35	15.87	104.67	102.19	20.49	100.75
Left Knee Flexion Strength (N*m)	Male	35	119.98	26.20	120.14	122.90	25.54	123.17
Right Knee Extension Strength (N*m)	Female	23	196.22	34.27	197.39	179.11	35.34	179.75
Right Knee Extension Strength (N*m)	Male	34	228.83	44.71	226.26	206.80	40.37	207.29
Left Knee Extension Strength (N*m)	Female	23	190.10	19.51	185.67	177.84	26.94	176.70
Left Knee Extension Strength (N*m)	Male	35	219.31	42.59	211.96	211.11	47.62	204.55

Table 3. Descriptive Statistics for Physiological Characteristics

	Sex	N	Pre			Post		
			Mean	SD	Median	Mean	SD	Median
VO2 Max (ml/kg/min)	Female	21	43.01	3.21	43.42	43.34	2.34	43.39
VO2 (ml/kg/min)	Male	30	48.52	4.79	48.89	49.22	4.47	49.12
Lactate Threshold (% VO2 max)	Female	20	35.64	2.35	35.24	36.49	2.31	36.57
Lactate Threshold (% VO2 Max)	Male	28	41.34	4.14	41.16	42.06	3.73	41.84
Anaerobic Capacity (W/kg)	Female	23	5.81	0.94	5.80	5.91	0.87	6.00
Anaerobic Capacity (W/kg)	Male	29	7.27	1.45	7.10	7.39	1.06	7.20
Anaerobic Power (W/kg)	Female	23	10.73	.75	10.60	10.38	.62	10.50
Anaerobic Power (W/kg)	Male	29	12.10	1.05	12.20	11.77	1.09	11.70

3.1 Body Composition

3.1.1 Body Fat Percentage

There was no significant interaction effect (p=0.916, partial η^2= 0.000) for body fat percentage. There was a significant main effect of time (p=0.010, partial η^2=0.109). Body fat percentage was significantly higher at the pre-timepoint (mean=21.34, standard error=0.65) compared to the post-timepoint (mean=20.29, standard error=0.54). There was also a significant main effect of sex (p<.001, partial η^2=0.959). Body fat percentage was significantly higher in women (mean=24.67, standard error=0.88) compared to men (mean=16.96, standard error=0.72).

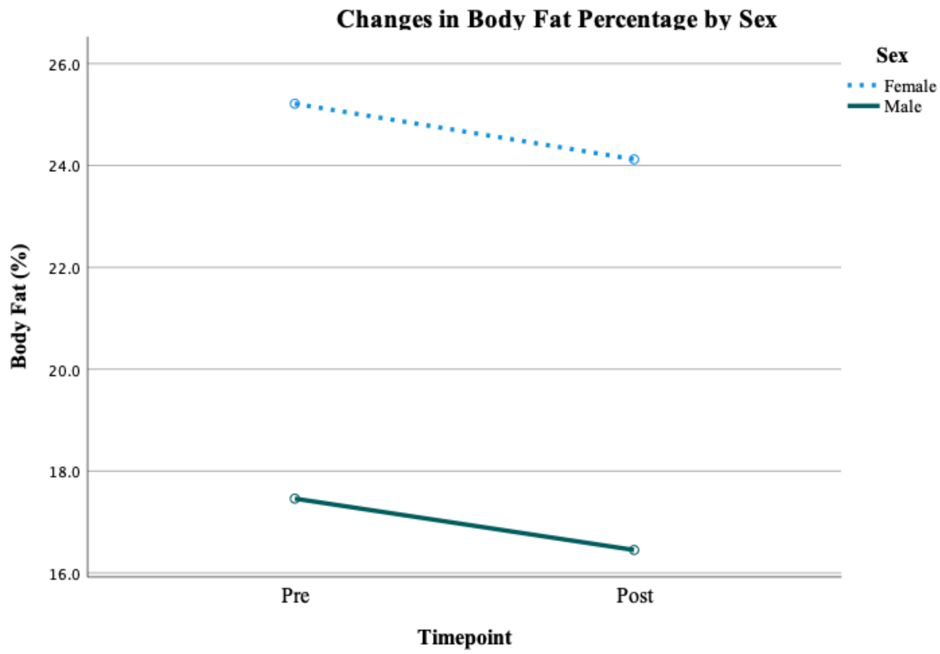

Figure 2. Changes in Body Fat Percentage by Sex

3.2 Strength

3.2.1 Core

There was no significant interaction effect ($p=0.857$, partial $\eta^2=0.001$) for trunk flexion strength. There was a significant main effect of time ($p<0.001$, partial $\eta^2=0.260$). Trunk flexion strength was significantly higher at the pre-timepoint (mean=192.77 Nm, standard error=3.99) compared to the post-timepoint (mean=172.49 Nm, standard error=3.62). There was also a significant main effect of sex ($p<0.001$, partial $\eta^2=0.384$). Trunk flexion strength was significantly higher in men (mean=200.62 Nm, standard error=3.84) compared to women (mean=164.64 Nm, standard error=4.74).

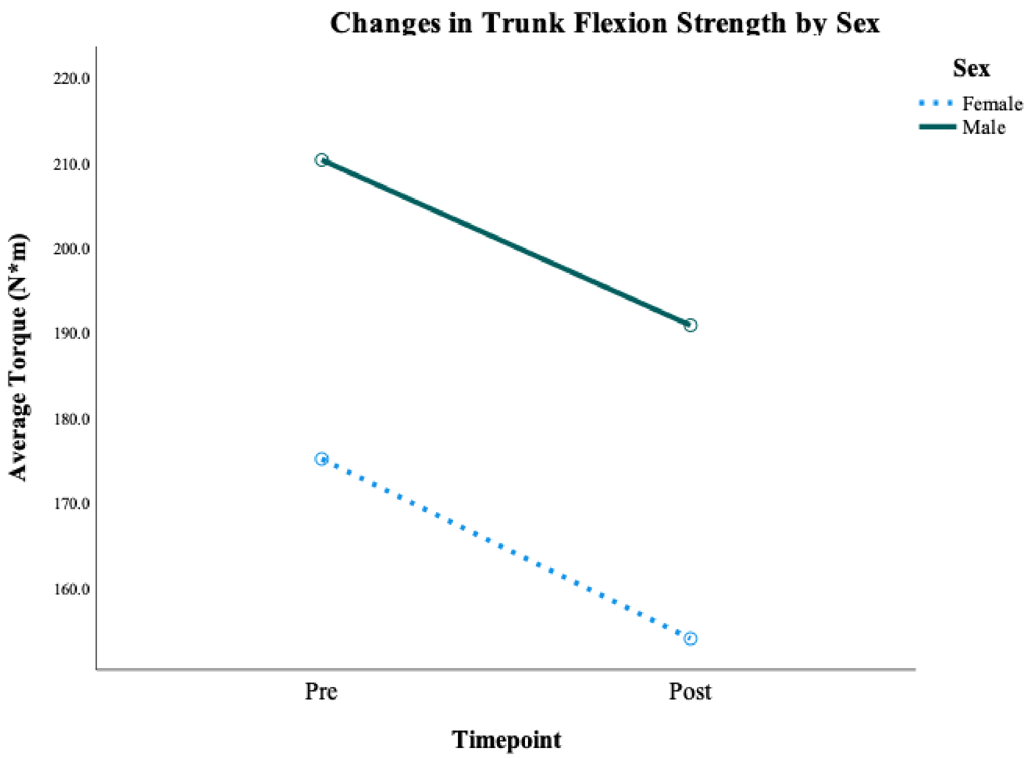

Figure 3. Chnages in Trunk Flexion Strength by Sex

There was no significant interaction effect ($p=0.284$, partial $\eta^2=0.020$) for trunk extension strength. There was a significant main effect of time ($p=0.003$, partial $\eta^2=0.150$). Trunk extension strength was significantly higher at the pre-timepoint (mean=299.10 Nm, standard error=8.84) compared to the post-timepoint (mean=272.83 Nm, standard error=8.71). There was also a significant main effect of sex ($p<0.001$, partial $\eta^2=0.329$). Trunk extension strength was significantly higher in men (mean=326.44 Nm, standard error=9.73) compared to women (mean=245.49 Nm, standard error=12.00).

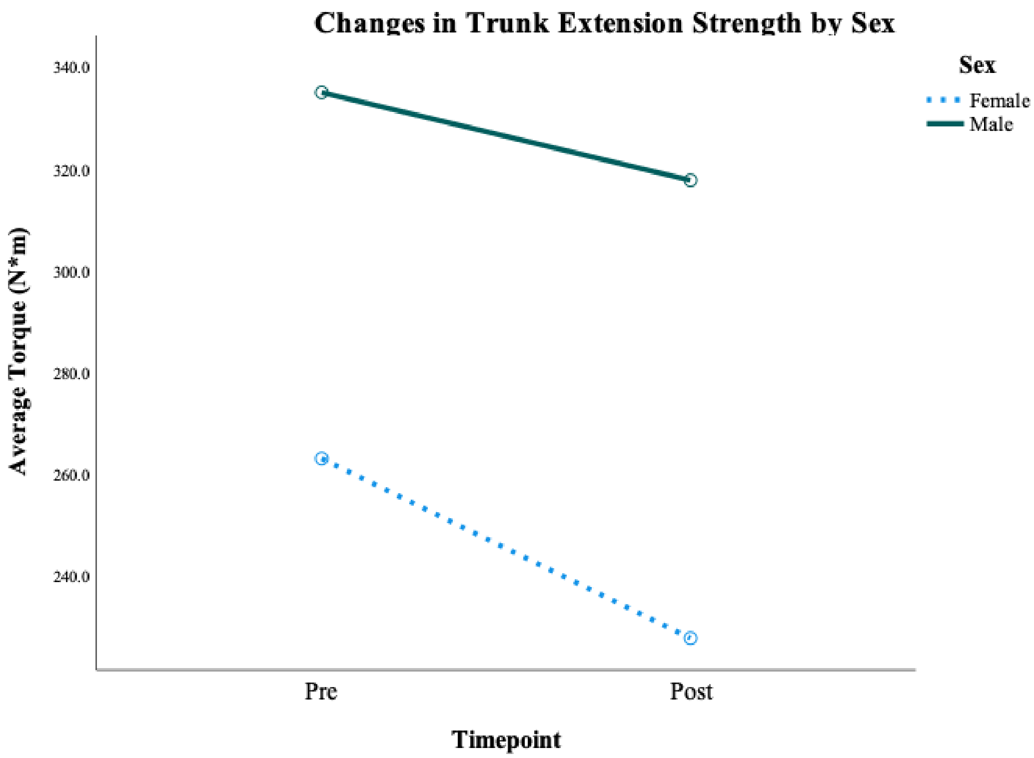

Figure 4. Changes in Trunk Extension Strength by Sex

3.2.2 Upper Extremity

There was no significant interaction effect (p=0.775, partial η^2=0.001) for right shoulder internal rotation (RSIR) strength. There was a significant main effect of time (p=0.011, partial η^2=0.107). RSIR strength was significantly higher at the pre-timepoint (mean=49.55 Nm, standard error=1.68) compared to the post-timepoint (mean=45.37 Nm, standard error=1.63). There was also a significant main effect of sex (p<0.001, partial η^2=0.434). RSIR strength was significantly higher in men (mean=57.06 Nm, standard error=1.81) compared to women (mean=37.87 Nm, standard error=2.27).

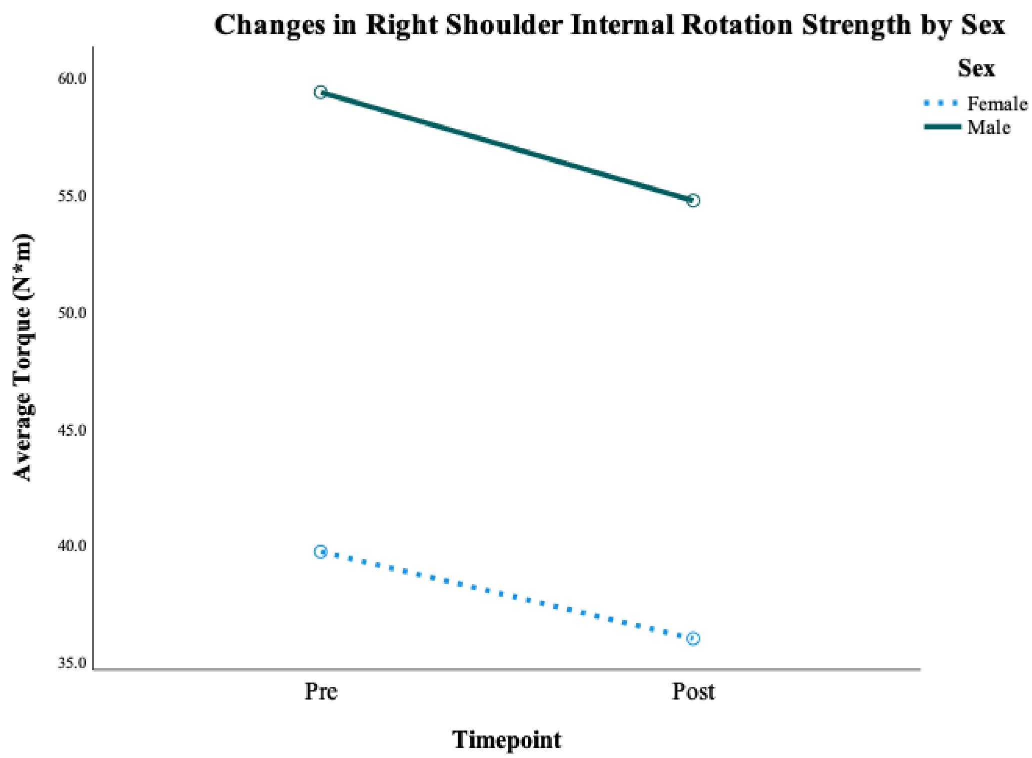

Figure 5. Changes in Right Shoulder Internal Rotation Strength by Sex

There was no significant interaction effect ($p=0.285$, partial $\eta^2=0.021$) for left shoulder internal rotation (LSIR) strength. There was a significant main effect of time ($p=0.004$, partial $\eta^2=0.138$). LSIR strength was significantly higher at the pre-timepoint (mean=47.40 Nm, standard error=1.44) compared to the post-timepoint (mean=43.47 Nm, standard error=1.37). There was also a significant main effect of sex ($p<0.001$, partial $\eta^2=0.469$). LSIR strength was significantly higher in men (mean=54.07 Nm, standard error=1.54) compared to women (mean=36.79 Nm, standard error=1.94).

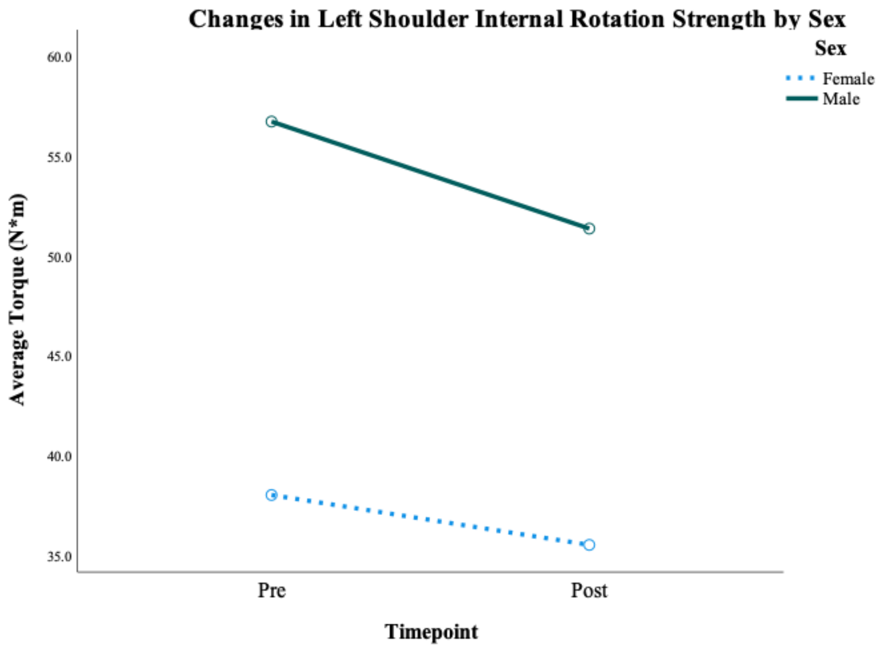

Figure 6. Changes in Left Shoulder Internal Rotation Strength by Sex

There was no significant interaction effect (p=0.633, partial η^2=0.004) for right shoulder external rotation (RSER) strength. There was not a significant main effect of time (p=0.119, partial η^2=0.042). However, there was a significant main effect of sex (p<0.001, partial η^2=0.561). RSER strength was significantly higher in men (mean=41.98 Nm, standard error=0.89) compared to women (mean=29.82 Nm, standard error=1.11).

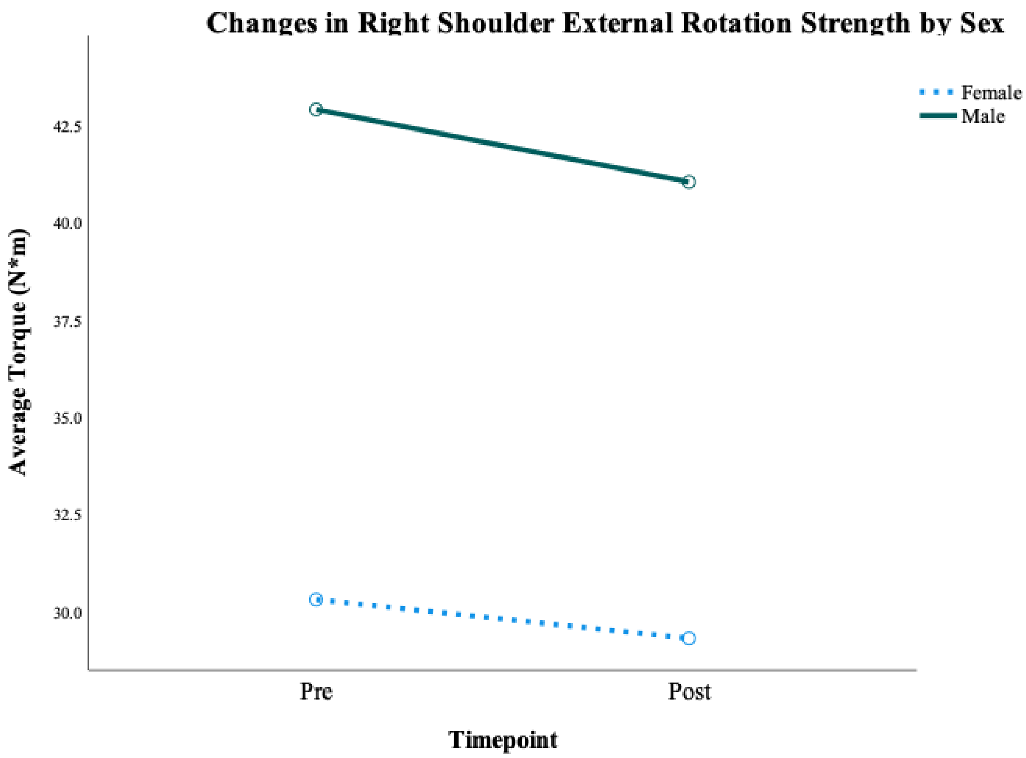

Figure 7. Changes in Right Shoulder External Rotation Strength by Sex

There was a significant interaction effect (p=0.008, partial η^2=0.122) for left shoulder external rotation (LSER) strength. Simple main effects of time were analyzed separately for men and women. There was no significant main effect of time for women (p=0.293, partial η^2=0.053), but a significant reduction in LSER strength for men (p=0.005, partial η^2=0.213).

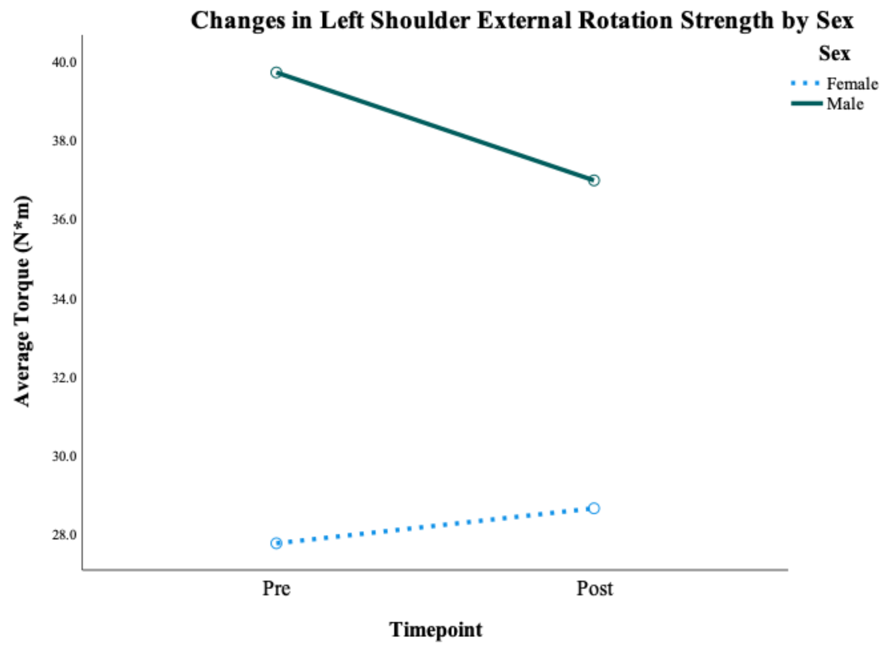

Figure 8. Changes in Left Shoulder External Rotation Strength by Sex

3.2.3 Lower Extremity

There was no significant interaction effect ($p=0.954$, partial $\eta^2=0.000$) for right knee flexion (RKF) strength. There was not a significant main effect of time ($p=0.223$, partial $\eta^2=0.027$). There was a significant main effect of sex ($p=0.003$, partial $\eta^2=0.154$). RKF strength was significantly higher in men (mean=122.31 Nm, standard error=3.47) compared to women (mean=105.01 Nm, standard error=4.22).

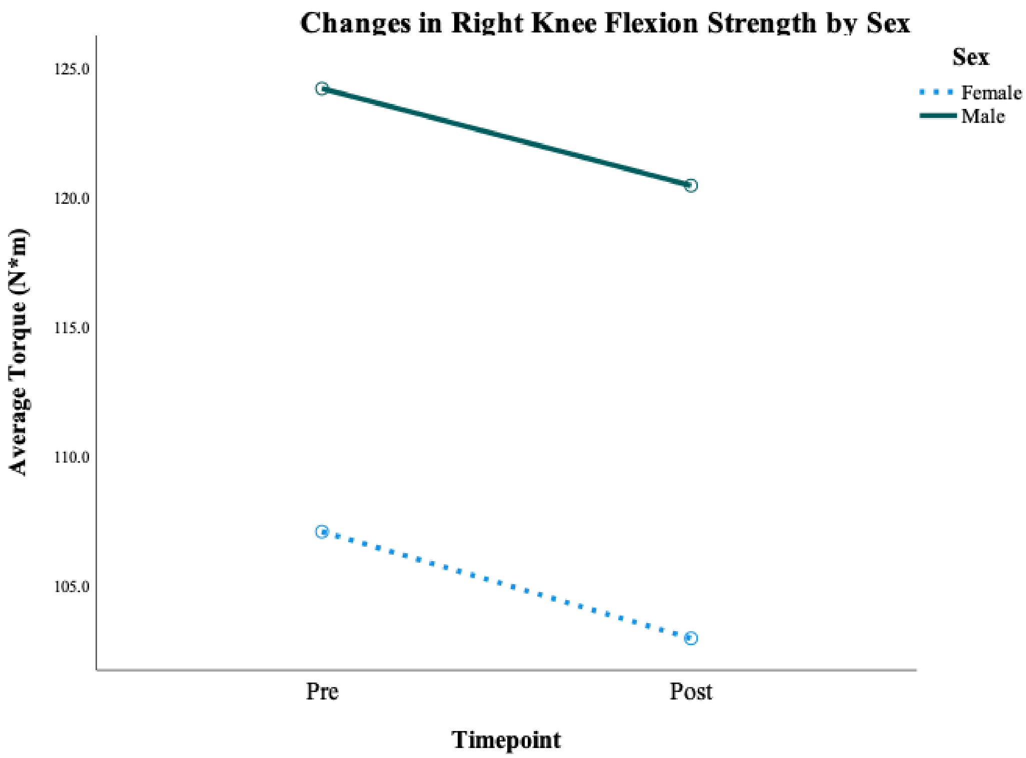

Figure 9. Changes in Right Knee Flexion Strength by Sex

There was no significant interaction effect (p=0.303, partial η^2=0.019) for left knee flexion (LKF) strength. There was not a significant main effect of time (p=0.966, partial η^2=0.000). There was a significant main effect of sex (p=0.002, partial η^2=0.156). LKF strength was significantly higher in men (mean=121.44 Nm, standard error=3.46) compared to women (mean=103.77 Nm, standard error=4.27).

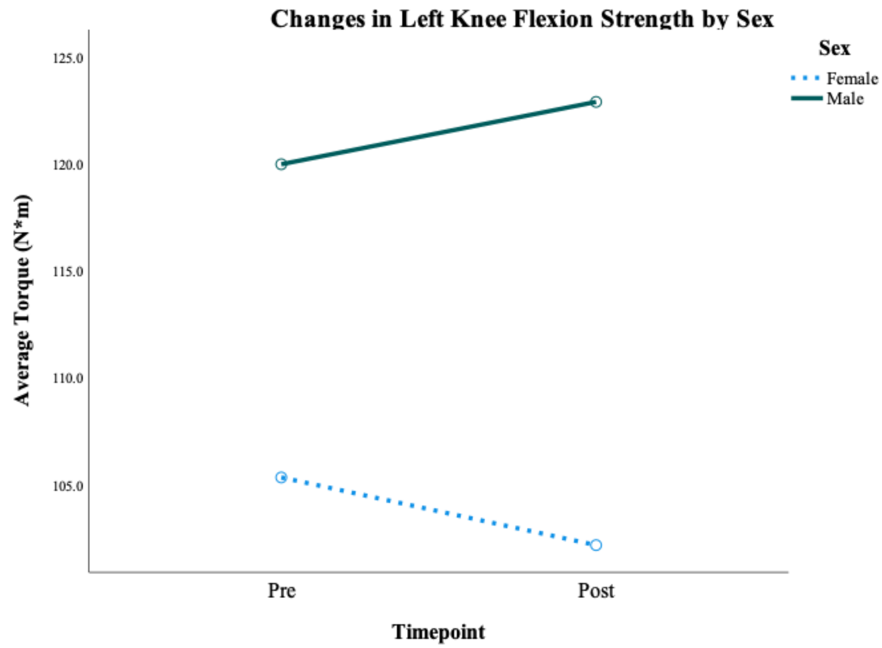

Figure 10. Changes in Left Knee Flexion Strength by Sex

There was no significant interaction effect ($p=0.613$, partial $\eta^2=0.005$) for right knee extension (RKE) strength. There was a significant main effect of time ($p<0.001$, partial $\eta^2=0.230$). RKE strength was significantly higher at the pre-timepoint (mean=212.53 Nm, standard error=5.52) compared to the post-timepoint (mean=192.95 Nm, standard error=5.19). There was also a significant main effect of sex ($p=0.003$, partial $\eta^2=0.153$). RKE strength was significantly higher in men (mean=217.81 Nm, standard error=6.07) compared to women (mean=187.66 Nm, standard error=7.38).

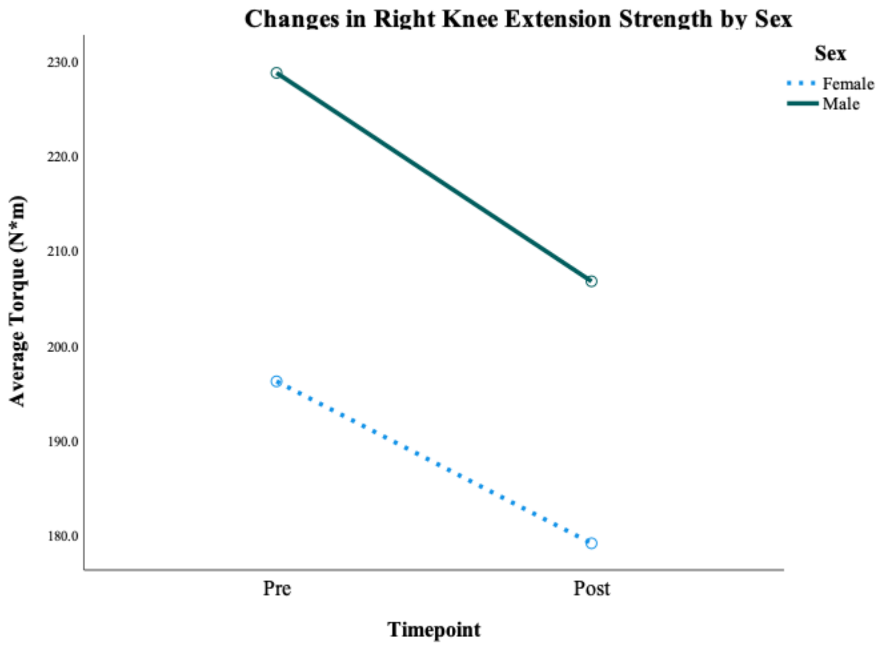

Figure 11. Changes in Right Knee Extension Strength by Sex

There was no significant interaction effect ($p=0.720$, partial $\eta^2=0.002$) for left knee extension (LKE) strength. There was not a significant main effect of time ($p=0.075$, partial $\eta^2=0.055$). There was a significant main effect of sex ($p<0.001$, partial $\eta^2=0.193$). LKE strength was significantly higher in men (mean=215.21 Nm, standard error=5.38) compared to women (mean=183.97 Nm, standard error=6.64).

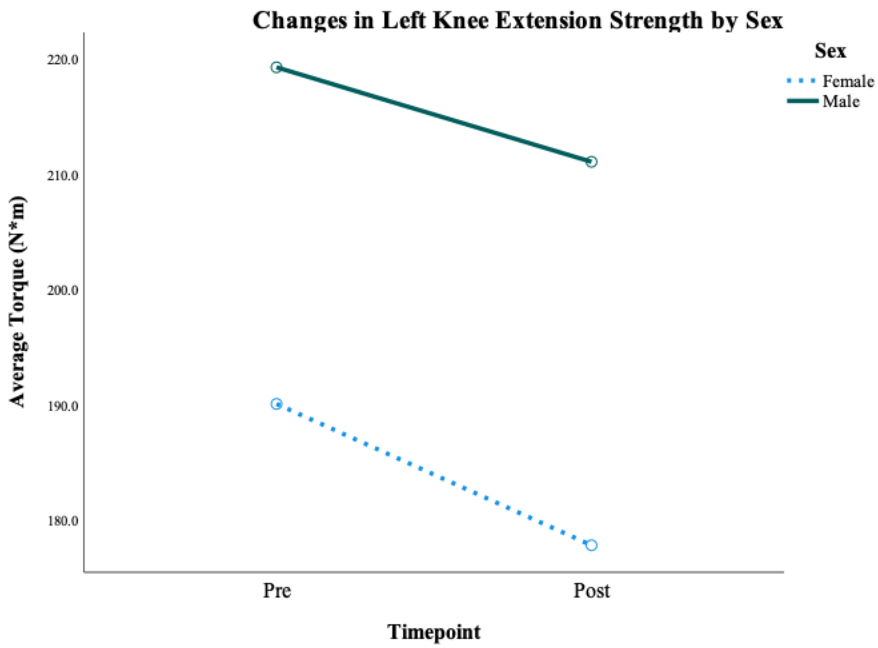

Figure 12. Changes in Left Knee Extension Strength by Sex

3.3 Physiological Characteristics

3.3.1 Aerobic Fitness

There was no significant interaction effect (p=0.689, partial η^2=0.003) for VO_2 max. There was not a significant main effect of time (p=0.249, partial η^2=0.027). There was a significant main effect of sex (p<0.001, partial η^2=0.377). VO_2 max was significantly higher in men (mean=48.87 ml/kg/min, standard error=0.67) compared to women (mean=43.18 ml/kg/min, standard error=0.80).

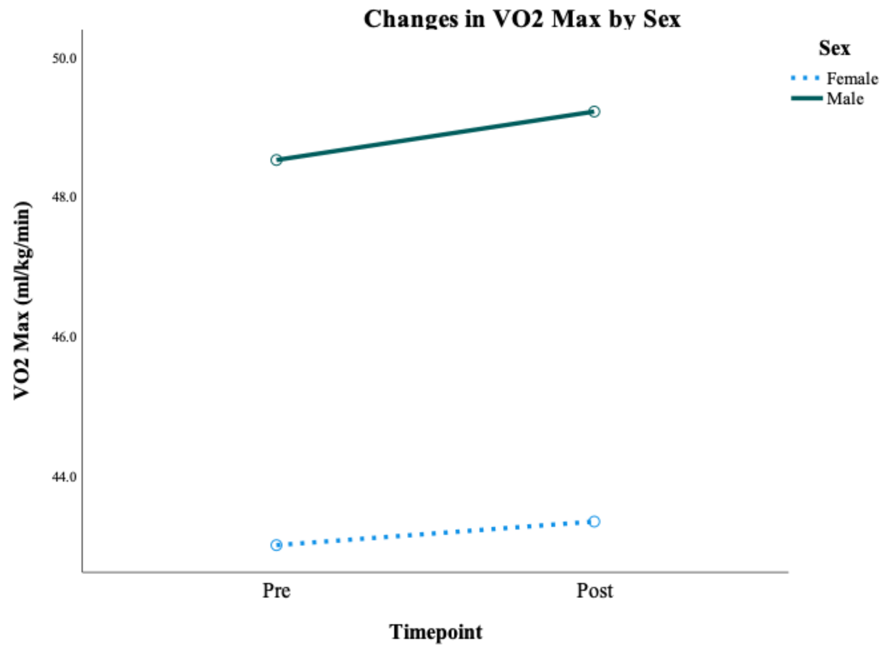

Figure 13. Changes in VO2 Max by Sex

There was no significant interaction effect ($p=0.908$, partial $\eta^2=0.000$) for lactate threshold. There was not a significant main effect of time ($p=0.161$, partial $\eta^2=0.042$). There was a significant main effect of sex ($p<0.001$, partial $\eta^2=0.508$). Lactate threshold was significantly higher in men (mean=41.70% of VO2 max, standard error=0.53) compared to women (mean=36.07% of VO2 max , standard error=0.62).

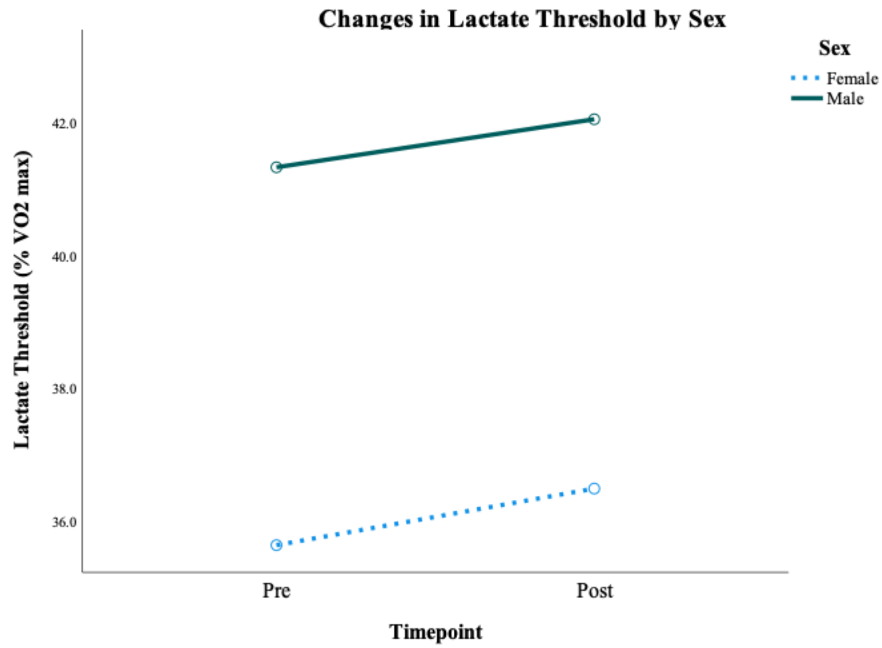

Figure 14. Changes in Lactate Threshold by Sex

3.3.2 Anaerobic Fitness

There was no significant interaction effect ($p=0.928$, partial $\eta^2=0.000$) for anaerobic capacity. There was not a significant main effect of time ($p=0.351$, partial $\eta^2=0.017$). There was a significant main effect of sex ($p<0.001$, partial $\eta^2=0.339$). Anaerobic capacity was significantly higher in men (mean=7.33 W/kg, standard error=0.19) compared to women (mean=5.86 W/kg, standard error=0.22).

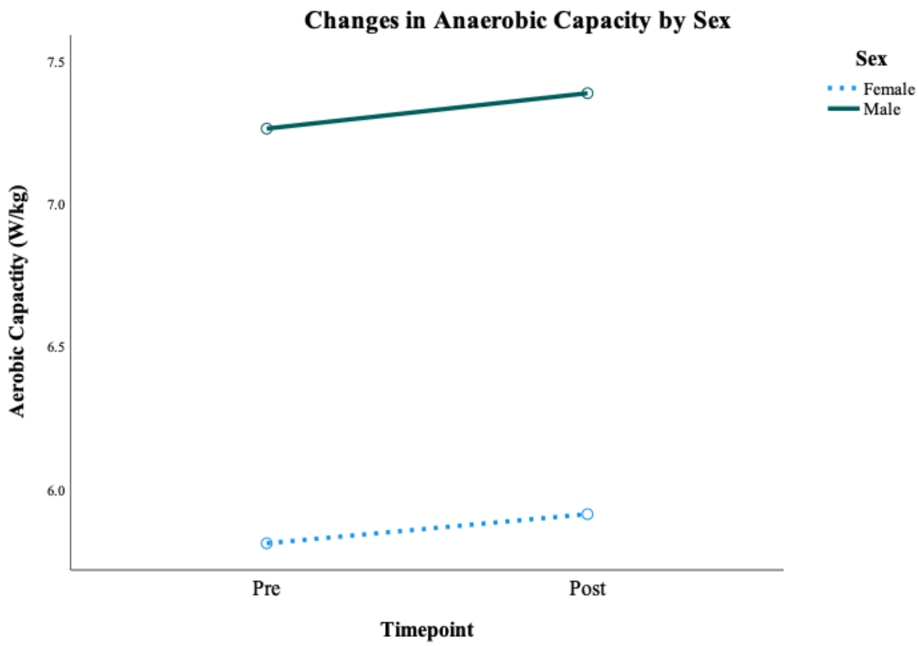

Figure 15. Changes in Anaerobic Capacity by Sex

There was a significant interaction effect (p=.001, partial η^2=0.196) for anaerobic power. Simple main effects of time were analyzed separately for men and women. There was no significant main effect of time for women (p=0.072, η^2=0.139), but a significant reduction in anaerobic power for men (p=0.002, η^2=0.305).

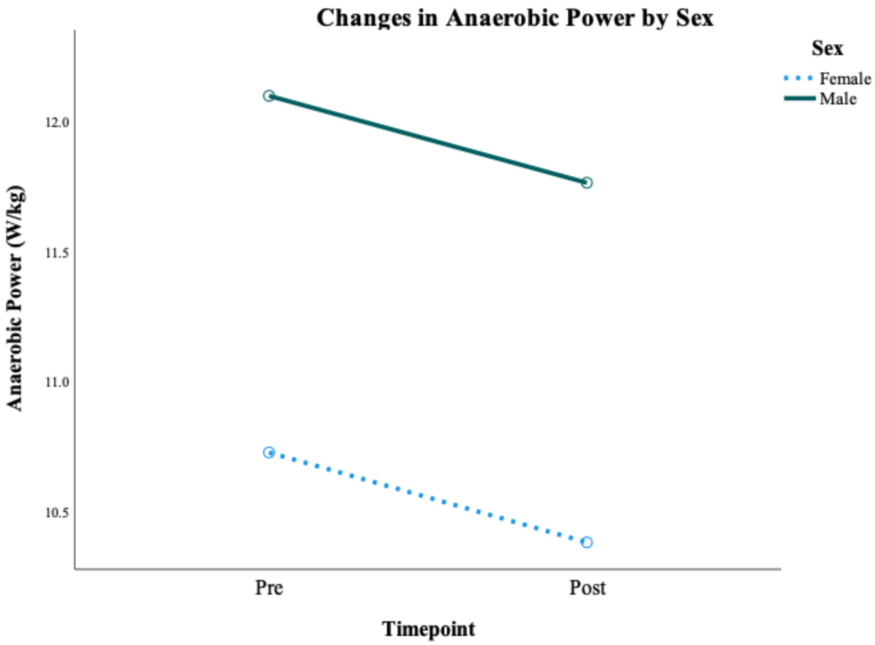

Figure 16. Changes in Anaerobic Power by Sex

4.0 Discussion

The rescindment of the direct ground combat assignment rule brought interest to the comparison of how women and men would change over time during training and assessments in MOS assignments. This study aimed to compare the changes in body composition, strength, and aerobic and anaerobic fitness in both female and male Marines. Understanding how these characteristics change throughout specific MOS training will provide insight into the effects of integration of women into combat roles. The results of this study indicate that time and sex have a significant effect on most of the characteristics investigated throughout this study, although not all. The following sections will go into further detail.

4.1 Body Composition

4.1.1 Body Fat Percentage

The first aim of the study was to examine and compare changes in body fat percentage among women and men after GCE ITF training and assessments. Results did show that there was a significant change in body fat percentage over time. Marines in this study averaged a lower body fat percentage at the post-timepoint compared to the pre-timepoint. Furthermore, there was a significant difference in body fat percentage among sex, with women having a higher body fat percentage compared to men.

According to the Department of Defense, body fat should not exceed 18% for all Marines, a standard which has proven to result in improved aerobic and anaerobic capacity and increased muscular strength. [20] Our results show that the average body fat percentage of women exceeded this standard regardless of timepoint. Men, on the other hand, had average body fat percentages under 18%. Based on the previously described study, women having a body fat percentage over 18% may negatively affect performance.

A study published in 2008 resulting in fat mass reduction after combat training supports the reduction in body fat percentage shown in the current study.[17] Reduction in body fat can be explained by relevant literature summarizing dietary assessments which have found that soldiers do not consume adequate calories to meet training needs.[51] According to the larger GCE-ITF study, 31% of males and 65% of females were not consuming adequate calories to meet their energy expenditure needs.[10] Women having significantly higher body fat percentage than men has been established by many prior studies which have attributed these differences to genetic, epigenetic, and hormonal factors.[52]

4.2 Strength

4.2.1 Core

The second aim of the study was to examine and compare core strength in women and men after GCE ITF training and assessments as determined by isokinetic trunk flexion and extension strength. There was no interaction between timepoint and sex for trunk flexion strength, but there was a significant different in trunk flexion strength over time. Interestingly, Marines had lower trunk flexion strength at the post-timepoint compared to at the pre-timepoint. There was also a significant difference in trunk flexion strength between sexes, with men having higher trunk flexion strength on average than women.

Results for trunk extension strength were the same. There was no interaction between timepoint and sex for trunk extension strength, but there was a significant difference in trunk extension strength over time and between sexes. Trunk extension strength was found to be lower at the post-timepoint compared to at the pre-timepoint, and men had higher trunk extension strength than women.

4.2.2 Upper Extremity

The third aim of this study was to examine and compare changes in upper extremity strength after ITF training and assessment after GCE ITF training and assessments as determined by isokinetic shoulder internal and external rotation strength.

Results show that while there was no interaction between timepoint and sex on right shoulder internal rotation (RSIR) strength, there was a significant difference over time as well as between sexes. Marines had lower RSIR strength at the post-timepoint compared to at the pre-timepoint and men had higher RSIR strength on average than women. Similar results were found for left shoulder internal rotation (LSIR) strength. There was no interaction between timepoint and sex, but there was a significant difference between strength over time and between sexes. Marines had lower strength at the post-timepoint compared to the pre-timepoint, and men had higher LSIR strength on average than women.

The effect of time on right shoulder external rotation (RSER) strength did not differ significantly between women and men. Additionally, changes in RSER strength over time were not significantly different whereas there was a significant difference in RSER strength between women and men. This study found that men had higher RSER strength than woman, on average.

The results show the effect of time on left shoulder external rotation (LSER) strength differed significantly between women and men. 12.2% of the variation in LSER strength is due to the interaction effect between time and sex. The effect of time on LSER strength was analyzed separately for women and men. Changes in LSER strength over time were not statistically significant for women, but there was a significant reduction in LSER strength for men over time.

Overall, men had stronger shoulder internal and external rotation strength on average compared to women which has been established in previous research involving Airborne Division Soldiers.[53]

4.2.3 Lower Extremity

The fourth aim of this study was to examine and compare changes in lower extremity strength after ITF training and assessment as determined by isokinetic knee flexion and extension. The effect of time on right knee flexion (RKF) strength did not differ significantly between women and men, and RKF strength over time was not statistically significant. There was a significant difference in RKF strength between women and men. 15.4% of the variation in RKF is due to sex differences and RKF strength was found to be significantly higher in men compared to women, on average.

The effect of time on left knee flexion (LKF) strength did not differ significantly between women and men, and the changes in LKF strength over time was not significant either. There was a significant difference in LKF between women and men, with men having higher RKF strength on average.

The effect of time on right knee extension (RKE) strength did not differ significantly between women and men, but there was a significant main effect of time. RKE strength was significantly lower at the post-timepoint compared to the pre-timepoint. Additionally, there was a significant difference in RKE strength between women and men. Men had higher RKE strength on average than women.

Left knee extension (LKE) strength did not change differently between women and men over time. Strength over time differed between women and men. Specifically, men had a significant reduction in strength over time, while women did not show a significant change. In addition, LKE strength did not decrease significantly from the pre-timepoint to the post-timepoint.

4.2.4 Strength Differences and Decrements

As described previously, many of the strength characteristics decreased over time. Miller et al. reported that upper body muscle mass is 50% higher and the lower body muscle mass is 30% higher in men compared to in women. This corresponds to 14% more muscle fibers and 35% larger muscle fibers.[54] Additionally, evidence suggests that skeletal muscle fiber-type composition is dependent on sex. Females tend to more type-I muscle fibers whereas men have more type-II muscle fibers. type-I, or slower-twitch muscle fibers, produce low power contractions over long periods of time whereas type-II, or fast-twitch muscle fibers, are more powerful, but fatigue more easily.[55] Men having more type-II muscle fibers may be one explanation of the strength differences in women and men. Another explanation could be the role of testosterone in men. The significantly higher levels of testosterone have been attributed to males having larger and stronger muscles, as well as a greater potential for muscle development.[56]

Prior research in Finnish soldiers has revealed reductions in lower extremity strength as determined by an isokinetic leg press after prolonged combat training periods. Strength returned to baseline level after loading decreased in the training protocol suggesting that rest may be vital in terms of optimizing strength in soldiers.[57] Energy deficits also have been reported to play a role in decrements in muscle strength and power. After eight weeks of military training involving restricted calorie intake, there was a 20% decline in maximal lifting strength and power output.[58]

4.3 Physiological Characteristics

4.3.1 Aerobic Fitness

The fifth aim of this study was to examine and compare changes in aerobic fitness after ITF training and assessment as determined by maximal oxygen consumption and lactate threshold. There was no significant difference in the effect of time and sex on VO_2 max. There was also no significant change in VO_2 max over time, but there was a significant difference in VO_2 max between women and men. The average VO_2 max for men was higher than that of women.

There was no significant difference in the effect of time and sex on lactate threshold, and there was no significant change in lactate threshold from the pre to post-timepoint. There was a significant difference in lactate threshold between women and men. The average lactate threshold for men was higher for men than compared to women.

There are multiple reasons that women tend to have lower VO_2 maxes than men such as women, on average, have smaller hearts, lungs, and lower hemoglobin than men. These factors limit their capacity to deliver oxygen to working muscles.[59] Some research also attributes differences in VO_2 max to increased body fat percentage. As percent body fat increases, VO_2 max decreases.[60] This finding is consistent with this study showing women to have an increased body fat percentage compared to men, as well as lower VO_2 maxes, on average.

4.3.2 Anaerobic Fitness

The last aim of this study was to examine and compare changes in anaerobic fitness after ITF training and assessment as determined by anaerobic power and capacity. There was no significant difference in the effect of time and sex on anaerobic capacity. While there was no significant change in anaerobic capacity over time, there was a significant difference in anaerobic capacity between women and men. Men had a higher anaerobic capacity than women on average.

There was a significant difference in the effect of time and sex on anaerobic power. There was no significant change in anaerobic power over time for women, but there was a significant reduction in anaerobic power over time for men. Men had a lower anaerobic power at the post-timepoint than they did at the pre-timepoint.

Our results are consistent with other studies finding that mean power was 35% higher in men compared to women. Similarly, peak power was reported to be 40% higher in men compared to women.[61] These sex differences have been attributed to differences in the glycolytic pathway. Women were found to have lower glycolytic activity possibly due to the smaller increase in plasma catecholamine during supramaximal efforts.[62] Additionally, intense military training has demonstrated decline in anaerobic capacity after training due to lack of optimal recovery strategies.[63]

4.4 Limitations

This study had several limitations. There was an uneven distribution of women and men in this study. In addition, the sample size could be expanded beyond 60 Marines. Increasing the sample size in the study could result in a more representative sample of the population as well as provide results with more precision.

As for the isokinetic strength testing, the Biodex has limited capability and specificity in testing certain muscle groups. For example, using the Biodex to test trunk strength can be quite challenging as it is difficult to isolate trunk muscles. Isokinetic testing is also not specific to movement patterns that are used in combat roles, such as dynamic tasks.

Furthermore, this study was conducted during experimental conditions. Marines were being assessed on their performance of tactical tasks during a defined study period, which is not reflective the typical training regimen of a Marine.

4.5 Future Directions

The results of this study provided evidence that there are sex differences in body composition, strength, and physiological fitness after ITF training and assessment phases in Marines. Future studies may want to further explore underlying physiological mechanisms that contribute to these differences such as hormonal or metabolic factors. Additionally, they would want to investigate how these differences may translate to military specific tasks and job performance.

4.6 Conclusion

This research aimed to observe and investigate how physical and physiological characteristics of both men and women change during ground combat MOS training. Based on a two-way measure analysis of variance, sex differences and time play a role in body composition, strength, and physiological characteristics. Optimizing training by using sex-specific interventions may decrease the differences between women and men. Decreasing the variability of strength and fitness differences could improve unit readiness. To optimize physical readiness, this data can be used to inform training and recovery strategies during intense period of physical training in combat MOS units.

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