

TIME AWAY FROM MANDATORY PHYSICAL TRAINING AND ITS EFFECT ON
MAXIMAL VO₂ IN ROTC CADETS

A Thesis
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

Kassie Georgette Krebsbach

In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE

Major Department:
Health, Nutrition, and Exercise Sciences

May 2011

Fargo, North Dakota

ABSTRACT

During the school year, cadets in ROTC programs are required to participate in mandatory physical training. However, during the summer months, training is not required. Changes can occur in VO_{2max} with both training and detraining. The purpose of this study was two-fold: (1) to determine if VO_{2max} changes over the summer in cadets returning to campus and (2) to determine if there is a difference in VO_{2max} between returning cadets and new cadets. Participants completed a graded exercise treadmill test to determine their VO_{2max} in the spring of 2010 and in the fall of 2010. The results show a significant decrease in the returning cadets' VO_{2max} from time point 1 (spring) to time point 2 (fall). No difference was noted between returning cadets' and new cadets' VO_{2max} . In conclusion, by providing the cadets with a program to be completed during extended breaks, a decrease in VO_{2max} could possibly be avoided.

ACKNOWLEDGMENTS

I would like to sincerely thank my advisor, Dr. Gary Liguori, for all of his assistance, guidance, and support during my time at NDSU. I would also like to show my gratitude to the members of my committee and also John Schuna, whom has been a tremendous help during this process. Lastly, I offer my regards to all of those who supported me in any respect.

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INTRODUCTION

Physical training plays an important role in the success of military cadets, including those enrolled in the Reserve Officers' Training Corps (ROTC) programs. Reserve Officers' Training Corp is a college-based program designed to focus on leadership development, problem solving, strategic planning, and professional ethics. Successful fulfillment of all military tasks is critical for members of the military, including ROTC cadets. Many of these tasks require a high level of physical fitness, which military members must sustain as long as they are enrolled (Roy, Springer, McNulty, & Butler, 2010). In order to ensure service members are optimally prepared to meet the physical demands of their missions, they are required to participate in regular training and physical fitness testing (Vanderburgh, 2007).

In the military, particularly ROTC programs, cardiovascular endurance and muscle endurance are most commonly measured. Therefore, regular physical training (PT) is often centered on these variables. Muscular endurance is the ability to create a force repetitively (Roy et al., 2010). In the military, muscular endurance is measured by completing the maximum amount of push-ups possible in two minutes (Physical Fitness Training: Army Field Manual, 1992). Cardiovascular endurance reflects the ability of the lungs, blood, heart, muscles, and other organs and organ systems to transport and utilize oxygen (Liguori & Carroll-Cobb, 2011). Depending on the branch of service, cardiovascular endurance is assessed by either the 1.5-mile run or the 2-mile run (Roy et al., 2010).

Measuring cardiovascular endurance helps not only to characterize an individual's ability to perform a certain task, but it can also be used to quantify progress in training regimen on performance (Foss & Keteyian, 1998). Participating in different levels of

exercise training can lead to increases in VO_{2max} , which would be beneficial when completing various physical tasks. Detraining, which is defined as a loss of training-induced adaptations in response to either the cessation of training or a considerable decrease in the training load, can have a negative impact on VO_{2max} , causing a loss in cardiovascular endurance (Roy et al., 2010). If one of the goals of an exercise program is to increase cardiovascular endurance, it is essential for the individuals to participate in a continuous training program. The purpose of this study was to examine how time away from mandatory physical training can affect VO_{2max} in ROTC cadets.

Research Questions

- 1) Does maximal oxygen uptake (VO_{2max}) change over the summer in cadets when training is not mandatory?
- 2) At the start of the school year, is there a difference between returning cadets' and new cadets' maximal oxygen uptake (VO_{2max})?

Limitations

- 1) Small sample size ($n = 49$)
- 2) Population limited to ROTC cadets, and therefore may not be generalizeable to non-cadets
- 3) No assessment of cadets physical activity during 3-month break

Definitions of Terms

Cardiorespiratory Fitness: the ability to perform large muscle, dynamic, moderate-to-high intensity exercise for prolonged periods of time (American College of Sports Medicine [ACSM], 2006).

Detraining: the loss of training-induced adaptations in response to either the cessation of training or a considerable decrease in the training load (Roy et al., 2010).

Endurance: the body's ability to continually accomplish the same task in a repetitive fashion (Roy et al., 2010).

Health-Related Fitness: the amount of physical training required to reduce the risk of disease or injury (U.S. Department of Health & Human Services, 2008).

Maximal Oxygen Uptake ($\text{VO}_{2\text{max}}$): the ability of the lungs, blood, heart, muscles, and other organs and organ systems to transport and utilize oxygen (Foss & Keteyian, 1998).

Performance-Related Fitness: the amount of physical training required to achieve a physical goal (U.S. Department of Health & Human Services, 2008).

Physical Fitness: the amount of physical training required to reduce the risk of disease or injury (U.S. Department of Health and Human Services, 2008).

LITERATURE REVIEW

Physical fitness can be separated into two categories: health-related fitness and performance-related fitness (U.S. Department of Health and Human Services, 2008). Health-related fitness is the amount of physical training required to reduce the risk of disease or injury, whereas performance-related fitness is related to the amount of physical training required to achieve a physical goal, such as climbing a mountain or completing a ten mile hike (USDHHS, 2008). The two categories of physical fitness are both important; however, members of the military focus more on performance-related fitness.

A goal of the military is to ensure that service members are improving or maintaining the required level of fitness to perform their mission tasks. In order to monitor fitness levels among its members, the military assesses performance-related fitness twice a year (Roy et al., 2010). As stated previously, cardiovascular endurance and muscle endurance are most commonly measured. Each military service conducts its own fitness test based on some variation of a distance run, push-ups, and sit-ups. Cardiovascular endurance is one of the main interests due to its importance in the successful fulfillment of military tasks (Physical Fitness Training: Army Field Manual, 1992).

Maximal Oxygen Uptake

According to the American College of Sports Medicine (ACSM) (2006), cardiorespiratory endurance is related to the ability to perform large muscle, dynamic, moderate-to-high intensity exercise for prolonged periods of time. Cardiovascular endurance is related to oxygen uptake; the more oxygen an individual can take in, transport, and consume at the cellular level, the more efficient he/she is at performing large muscle, dynamic, moderate-to-high intensity exercise for extended periods of time (Bassett

& Howley, 2000). This phenomenon is typically referred to as $\text{VO}_{2\text{max}}$, which, in addition to physical activity, is dependent on age, gender, body size, body composition, and genetics (Foss & Keteyian, 1998). Maximum VO_2 results can vary greatly. The average $\text{VO}_{2\text{max}}$ for a sedentary individual is about $35 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ (Wilmore & Costill, 2005). Elite endurance athletes often average $70 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, but can reach as high as $94 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ (Wilmore & Costill, 2005). Generally, the $\text{VO}_{2\text{max}}$ of females is approximately 15% to 25% below that of males. Reasons for this are likely threefold; females have more essential body fat than males, the hemoglobin concentration of females is about 5% to 20% lower than in males, and average physical activity levels differ between genders (Foss & Keteyian, 1998). Hemoglobin transports oxygen from the lungs to the skeletal muscles. Therefore, a reduced hemoglobin concentration would contribute to a lower $\text{VO}_{2\text{max}}$ (Foss & Keteyian, 1998). In addition to gender having an influence on $\text{VO}_{2\text{max}}$, genetics can also play a role. It is estimated that genetics is responsible for about 20% to 30% of an individual's $\text{VO}_{2\text{max}}$ (McArdle, Katch, & Katch, 2005). Age is also a factor that can have an effect on an individual's $\text{VO}_{2\text{max}}$. Although it varies greatly by individual and training programs, in general, $\text{VO}_{2\text{max}}$ decreases steadily with age. Beyond age 25, $\text{VO}_{2\text{max}}$ declines at about 1% per year. However, active individuals are able to retain a relatively high $\text{VO}_{2\text{max}}$ as they age. Research continues to show that one's habitual level of physical activity determines changes in $\text{VO}_{2\text{max}}$ to a greater extent than chronological age (McArdle et al., 2005).

Assessing $\text{VO}_{2\text{max}}$

ACSM (2006) recommends assessing cardiovascular endurance for the following reasons: (1) educating participants about their current health-related fitness status, (2)

providing data that are helpful in developing safe and effective exercise programs, (3) collecting baseline and follow-up data that allow evaluation of participants' progress, (4) motivating participants by establishing reasonable and attainable fitness goals, and (5) stratifying cardiovascular risk. The reasons listed above can be applied to the military; assessing the cadets' cardiovascular endurance is beneficial for collecting data to use for developing a safe and effective exercise program, and then to evaluate progress being made among the cadets' fitness levels. A study by Berthouze et al. (1995) investigated the relationship between mean habitual daily energy expenditure and maximal oxygen uptake in healthy participants ranging in age from 16 to 88. A strong relationship was found between the participants' mean habitual daily expenditure and VO_{2max} ($r = 0.916$; $N=120$; $P < 0.0001$). The study also found that mean habitual daily energy expenditure spent in physical activity seemed to be the greatest determinant in the variation of VO_{2max} (89.35%). Other variables were found to be involved in the variation of VO_{2max} as well, but had a much smaller contribution: age (6.92%), former athletes who had considerably reduced or stopped their training (2.45%), body mass (0.85%), and gender (0.43%). These results suggest that an important factor in the variation of VO_{2max} is the total quantity of energy expenditure. Members of the military participate in mandatory physical training, which increases their total volume of energy expenditure. By participating in physical training daily, it may help to increase an individual's VO_{2max} , which in turn can help them to perform tasks more efficiently (Berthouze et al., 1995).

Measurement of VO_{2max} & Protocols

Currently, the most accurate method for determining energy expenditure is the doubly labeled water (DLW) method. Once DLW has been administered, the individual

may go about engaging in their normal daily tasks and body secretions such as saliva and urine are collected and recorded, while the influx of water and CO₂ determines the actual energy expenditure of the individual during the test (Schoeeler, 1988). The DLW method is primarily a laboratory-based research method and is often impractical due to the expense and time required to collect and record the data (Melanson & Freedson, 1996).

The best measure of an individuals' maximum oxygen consumption is indirect calorimetry. Measuring VO_{2max} with indirect calorimetry requires the participant to complete a graded exercise test until exhaustion. While completing the test, the participant is required to wear a mask over their mouth or a mouthpiece in their mouth with the nose clipped shut. Attached to the mask is a metabolic cart, which measures the amount of carbon dioxide expired and the amount of oxygen consumed (Vanhees, et al., 2005). Indirect calorimetry can easily be reproduced in a laboratory setting and is both accurate and reliable (Vanhees et al., 2005). In addition to indirect calorimetry, submaximal testing options are also available that can be used to predict VO_{2max}. Submaximal testing consists of tests which can be easily administered and need little or no equipment (Kline et al., 1987).

Criteria used to establish whether a true VO_{2max} has been attained have been heavily debated (Midgley, McNaughton, Polman, & Marchant, 2007). One procedure that has been used to indicate true VO_{2max} is the oxygen uptake (VO₂) plateau. A VO₂ plateau is defined as a small or no increase in VO₂ in response to an increase in work rate and shows that the rate of oxygen transport and utilization has reached its limit (Taylor, Buskirk, & Henschel, 1955). This might equate to a change in VO₂ of less than 2.1 mL·kg⁻¹·min⁻¹ or less (Foss & Keteyian, 1998). Other criteria for maximum oxygen uptake are based on surpassing

threshold values for the respiratory exchange ratio ($R > 1.10$) and heart rate (± 10 beats/min of age-predicted maximal heart rate) during the exercise test (Foss & Keteyian, 1998). Criteria for determination of maximal oxygen uptake vary across populations and studies; therefore it is difficult to find uniformity in testing procedures (Midgley, et al., 2007). Reasons for not achieving a true maximum VO_2 might include age, lack of motivation, chest pain, light headedness, or early fatigue (Foss & Keteyian, 1998).

VO_2 Testing Protocols

One of the most widely-used protocols for determining $\text{VO}_{2\text{max}}$ on the treadmill is the Bruce protocol. The Bruce protocol provides excellent accuracy when determining $\text{VO}_{2\text{max}}$ ($r=.92$, $\text{SEE}=3.1 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) with the testing procedure being standardized for all participants (Bruce et al., 1973). The standardized approach requires all participants to advance from one stage to the next at the same speed and grade. This standardized approach is beneficial because participants are compared from the same exercise intensity requirements and total exercise time can be used as an objective measure to accurately classify participants according to cardiovascular fitness (Bruce et al., 1973). The Bruce protocol was designed with sizeable increases in exercise intensity from one stage to the next ($8\text{-}12 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) in order to evaluate participants in a time-efficient manner, as this protocol rarely lasts beyond 15 minutes (Bruce et al., 1973). However, these abrupt increases in exercise intensity can be difficult for some participants to tolerate, which can result in premature termination of the test. Although the Bruce protocol permits evaluation across a broad spectrum of fitness and can also be used in cardiac patients, some participants may find the protocol not individualized to their own capabilities, considering

the increases in exercise intensity are the same for all participants during the test regardless of the individual's capabilities.

Unlike the sizeable increases in exercise intensity seen in the Bruce protocol, the Balke protocol has smaller increases per stage. The participant walks on a treadmill to exhaustion, at a constant walking speed while incline is increased every one or two minutes (Foss & Keteyian, 1998). There are several variations of the Balke test that are used, with variations in the treadmill speed, time at each level and/or increase in incline. The Balke protocol was developed as a clinical test to determine peak VO_2 in cardiac patients, though it can also be used to estimate cardiovascular fitness in athletes (Foss & Keteyian, 1998).

Another option for $\text{VO}_{2\text{max}}$ testing is to choose an individualized and participant-friendly test. For example, George (1996) developed the Arizona State University (ASU) maximal treadmill protocol that yields similar predictive accuracy ($R_{\text{adj}} = .95$, $\text{SEE} = 2.13 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) as the Bruce protocol for individuals 18-29 years. The ASU maximal treadmill protocol is individualized and more gradual in its increases in exercise intensity from one stage to the next. During the test, individuals self-select a comfortable exercise pace (walking or jogging) based on their own capabilities, and then maintain that pace throughout the entire test while only the grade is increased 1.5% every minute. In the George et al. (2007) study, the average duration of the ASU test was 11 to 17 minutes, including the 5-10 minute warm-up. Results from the study indicated that treadmill speed ($r = .583$) explained the largest amount of variance in $\text{VO}_{2\text{max}}$ scores followed by treadmill grade ($r = .356$), age ($r = -.197$), gender ($r = .183$), and BMI ($r = -.148$), respectively. In the Spackman, George, Pennington, & Fellingham (2001) study, the ASU maximal treadmill protocol was compared to the Bruce treadmill protocol. The gradual increase in intensity

during the ASU test is why the majority (93.8%) of participants preferred the ASU protocol over the Bruce protocol (Spackman et al., 2001). One of the disadvantages to the ASU protocol is that its individualized nature makes it impractical to compare the exercise response of participants at the end of each stage or to be able to compare ending treadmill times at the end of the test, which may be valuable in the clinical setting (George et al., 2007).

In addition to maximal tests, there are also many submaximal testing options that can be used to predict $\text{VO}_{2\text{max}}$, such as walking (Kline et al., 1987), jogging (George, Vehrs, Allsen, Fellingham, & Fisher, 1993), cycling (Astrand & Rhyming, 1954), and stepping (Jette, Campell, Mongeon, & Routhier, 1976). The accuracy of these submaximal tests in predicting $\text{VO}_{2\text{max}}$ is acceptable ($R = .75-.89$, $\text{SEE} = 3-5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$), however, maximal exercise test protocols are more precise for detecting change in $\text{VO}_{2\text{max}}$ over time.

The Rockport Walk Test is one of the more popular submaximal walking tests used to predict $\text{VO}_{2\text{max}}$. The test requires participants to walk one mile as fast as possible on a level surface. A heart rate is obtained immediately upon completion of the walk as well as the time for walking the mile. The test was developed and validated on subjects 30-69 years old, but a correction factor can be applied for college-aged subjects. The Rockport Walk Test provides a valid sub-maximum assessment for $\text{VO}_{2\text{max}}$ estimation ($r = 0.88$, $\text{SEE} = 4.4 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) (Kline et al., 1987).

The 1-mile jog test was developed as a submaximal field test to estimate $\text{VO}_{2\text{max}}$ (George et al., 1993). The objective of the test is for participants to jog one mile at a comfortable pace. In order to help ensure that a submaximal level of exertion is sustained, elapsed jog time needs to be greater than eight minutes for males and greater than nine

minutes for females. At the completion of the mile, heart rate should be taken within 15-20 seconds. The accuracy of prediction for the 1-mile jog test is acceptable ($r = 0.87$, $SEE = 3.0 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) (George et al., 1993).

Submaximal tests do have advantages such as allowing for mass testing, requiring minimal equipment, tending to be more enjoyable for the participant, and lowering the risk for cardiovascular complications during the exercise. Maximal protocols do, however, provide a more precise measure of the participants' physiological capacity. The information acquired from VO_2 testing can be beneficial when calculating safe and effective exercise intensity levels, evaluating progress, and establishing reasonable and attainable fitness goals for participants (ACSM, 2006).

Military physical fitness testing is constrained by the logistics of test administration, which includes field settings, minimal requirement for equipment, and time required to administer. Each military service uses its own physical fitness test composed of some variation of a distance run, push-ups/pull-ups/flexed arm hang, and sit ups (Roy et al., 2010). Depending on the branch of service, the standard test used to measure cardiovascular endurance is either the 1.5-mile run or the 2-mile run (Roy et al, 2010). In the majority of studies, the 1.5-mile and 2-mile run has shown good or excellent correlation to treadmill-measured $\text{VO}_{2\text{max}}$ (Mello, Murphy, Vogel, 1988; Knapik, 1989). In the Mello et al. (1989) study, correlation between a treadmill $\text{VO}_{2\text{max}}$ and two mile run time for males and females, were $r = 0.91$ and $r = 0.89$, respectively.

Training Effect on $\text{VO}_{2\text{max}}$

Changes can occur in $\text{VO}_{2\text{max}}$ with both physical training and detraining. Such changes include myocardial morphological changes that increase maximal stroke volume,

capillarisation of skeletal muscle, myoglobin concentration, and oxidative capacity of type II skeletal muscle fibers which are associated with the enhancement of $\text{VO}_{2\text{max}}$ (Midgley, McNaughton, & Wilkinson, 2006). Participating in various levels of exercise can lead to increasing one's aerobic capacity, which would be beneficial when completing various physical tasks. One of the goals of the military's physical training program is to ensure service members are prepared to meet the physical demands of the mission without incurring injury (Roy, et al., 2010).

The minimum training intensity that elicits the enhancement of $\text{VO}_{2\text{max}}$ is highly dependent on the initial $\text{VO}_{2\text{max}}$ of the individual (Swain & Franklin, 2002). In untrained individuals, training intensities of 40-50% $\text{VO}_{2\text{max}}$ are able to increase $\text{VO}_{2\text{max}}$ (Midgley, et al., 2006). Others suggest that training should be done at approximately 75% $\text{VO}_{2\text{max}}$ because myocardial stress, and therefore, the stimulus for myocardial adaptation, are greatest at this intensity (MacDougall & Sale, 1981). Mader (1991) suggests training should be done between 60-80% of $\text{VO}_{2\text{max}}$, primarily based on the premise that higher training intensities are detrimental because of mitochondrial degeneration at high oxidation rates. Individuals, who are well trained physically, may need to train at higher percentages of $\text{VO}_{2\text{max}}$ to show any type of improvement in their $\text{VO}_{2\text{max}}$. An increase of 15% to 20% is generally seen for an individual who was sedentary before training and who trains at 75% of his or her capacity three times per week, 30 minutes per day, for 6 months (Wilmore & Costill, 2005). The $\text{VO}_{2\text{max}}$ of a sedentary individual can increase from $35 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ to $42 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ if the program above is followed (Wilmore & Costill, 2005). To a certain extent, greater improvements can be expected with greater intensity and/or duration of

exercise. The range for the amount of aerobic improvement is reflected in the mode, frequency, duration, and intensity of the exercises performed (Midgley et al., 2006).

Changes in $\text{VO}_{2\text{max}}$ can also occur due to detraining, which is when the amount of training an individual is accustomed to either decreases or stops completely. The magnitude of the performance decline following a period of detraining appears to be related to initial fitness level, total time under reduced or absence of training stimuli, and whether the individual reduces their amount of training, or completely stops training (Mujika & Padilla, 2000). The maximal oxygen uptake of fit individuals declines markedly during long-term (more than four weeks) detraining, whereas recently acquired $\text{VO}_{2\text{max}}$ gains are completely lost (Mujika & Padilla, 2000). These changes are partly due to reduced blood flow, cardiac dimensions, and ventilatory efficiency, resulting in lower stroke volume and cardiac output, despite increased heart rates (Mujika & Padilla, 2000). Highly trained athletes have been shown to decrease their maximal oxygen uptake by 6 to 14% during a training cessation of three to six weeks (Coyle, Martin, Bloomfield, Lowry, & Holloszy, 1985). However, Madsen, Pederson, Djurhuus, and Klitgaard (1993) reported that endurance capacity can vary considerably during detraining without changes in $\text{VO}_{2\text{max}}$. Training cessation results in larger declines in physiological and performance parameters when compared to a reduced training approach, therefore it is important to maintain some reduced training program during transition periods (Garcia-Pallares, Carrasco, Diaz, Sanchez-Medina, 2009).

Summary

A variety of methods are available to assess $\text{VO}_{2\text{max}}$, each having its own unique advantages and disadvantages. Indirect calorimetry is valid and reliable, and the most

commonly used lab technique for determining cardiovascular endurance. Military personnel are required to maintain adequate levels of cardiovascular endurance, which is assessed through either a 1.5 or 2 mile run. Assessing cardiovascular endurance is just one part of the battery of physical tests military cadets participate in annually, along with tests of mobility, strength, and flexibility (Roy et al., 2010; Physical Fitness Training: Army Field Manual, 1992). Detraining is an issue for ROTC cadets, as their mandatory physical training does not apply during summer months. Therefore, this paper will investigate the effect potential summer detraining has on VO_2 levels of ROTC cadets.

METHODS

Participants

Participants were recruited from all currently enrolled Tri-College ROTC cadets. Of 51 currently enrolled cadets, 49 completed all aspects of this study. There were 32 returning cadets and 17 new cadets. The Institutional Review Board granted approval and informed consent was received from each participant as required, prior to initiating the study.

Instrumentation

Height

A Seca Road Rod 214 portable stadiometer (Seca, GmbH & Co. KG, Hamburg, Germany) was used to measure the height of the participants. Shoes were removed for all measurements, and the individual stood straight up with their back against the stadiometer. Participants were instructed to look straight ahead and inhale prior to the measurement. The measuring slide was then pressed lightly on the individual's head and the measurement was read in inches.

Weight

Weight for all participants was measured using a digital scale (Health O Meter model 751 KLS. Jarden Consumer Products, Boca Raton, FL). Participants wore minimal clothing for weight, removed their shoes and stepped onto the scale for their reading. Before the treadmill $\text{VO}_{2\text{max}}$ test began, a research assistant weighed each participant to the nearest tenth of a pound, which was then entered into the computer.

Heart Rate

Following the height and weight measurements, a Polar® Accurex II heart rate monitor strap (Polar USA, Lake Success, NY) was then attached to the participant's chest to measure heart rate during the treadmill test. The monitor was applied tightly to prevent it from slipping while the test was being conducted. A research assistant continuously monitored the participant's heart rate during the treadmill test and the maximum heart rate reached was recorded at completion.

Maximal Oxygen Uptake

A MedGraphics® Ultima™ Metabolic Cart (St. Paul, MN) was used to complete the $\text{VO}_{2\text{max}}$ treadmill test. The metabolic cart measured expired airflow by means of a pneumotach connected to the mouthpiece. Prior to each testing session, the pneumotach was calibrated with a 3 L syringe. The gas analyzers were also calibrated before each test.

The computer software program used with the metabolic cart was Breeze 6.2.055. All of the necessary information was entered into the program in order to calculate each participant's $\text{VO}_{2\text{max}}$. During the test, the research team was able to monitor the participant's respiratory exchange ratio and heart rate. Upon completion of the test, the program calculated the individual's $\text{VO}_{2\text{max}}$, which was then recorded by the research assistant.

The treadmill used during the $\text{VO}_{2\text{max}}$ test was the Trackmaster® TMX 425C (Newton, KS). The entire $\text{VO}_{2\text{max}}$ test was completed on the treadmill using a modified Taylor protocol, which required the participant to run at a constant speed with an increase in incline of one percent each minute (Taylor et al., 1955).

Procedures

All participants were tested in the Human Performance lab between 6:00 a.m. and 9:00 a.m. Initial setup of the metabolic cart entailed calibration of the pneumotach using a 3-liter syringe. In addition, gas analyzers were re-calibrated before each participant began their test by testing the analyzer's ability to measure a known concentration of reference gas. The metabolic cart measured expired airflow by means of a pneumotach connected to the mouthpiece. Barometric pressure was checked using a mercury barometer, temperature was checked with a thermometer, and both numbers were entered into the computer program.

On each day of testing, participants were instructed to refrain from physical activity prior to reporting to the lab. Depending on the time they were assigned, participants arrived at the lab between 6:00 a.m. and 8:30 a.m. Immediately upon arrival, it was confirmed that a consent form had been signed. The participant's visit to the lab consisted of three tests including the medicine ball throw, force plate push-up, and the treadmill $\text{VO}_{2\text{max}}$ test. Before testing began, students completed a brief five minute dynamic warm-up consisting of 8-10 exercises, including but not limited to skipping, sideways shuffling, high knees, etc. The first test completed was the medicine ball throw, which involved throwing the medicine ball as far as possible while sitting up against the wall with legs extended straight out. The second test was the force plate push-up test where the individual completed three separate push-ups, pushing up off of the force plate as quickly as possible. Upon completion of the first two tests, the individuals then moved onto the treadmill test. Before the treadmill test began, a member of the research team equipped the participant with a Polar® heart rate monitor. The individual's weight was taken with a digital scale

and height was measured with a portable stadiometer. The information was then entered into the computer program, Breeze, which would eventually calculate the predicted $\text{VO}_{2\text{max}}$. The treadmill protocol was then explained in detail to the individual. The protocol used was a modified Taylor protocol that used 7 mph as the constant speed with the grade increasing one percent every minute (Taylor, et al., 1955). Duration of the warm-up was two minutes during which time the participant ran at seven miles per hour at an even grade. During the warm-up, a member of the research team explained the maximum test in detail to the participant. At this time, they were reminded that the test required them to exert maximum effort, however whenever they felt they needed to terminate the test, they were allowed to do so. Individuals were instructed to step onto the side rails of the treadmill after completion of the warm-up. At this time, the mouthpiece and the nose clip were applied. When the participant was ready, they were allowed to step back onto the moving treadmill belt, which was when the actual max test began. During the test, the initial grade was set at zero; individuals maintained a 7 mph pace throughout the test while the incline was increased one percent every minute, with participants going until exhaustion. While the participant performed the test, heart rate, respiratory exchange ratio (RER) and oxygen uptake were being monitored to help determine the amount of effort that was being put forth. Hand signals were explained before beginning the test, so the administrator of the test and the participant could communicate effectively. The participant was in control at all times and was able to press the emergency stop button if needed, which would result in an immediate stopping of the treadmill. Once the participant reached exhaustion and had decided to terminate the test, the administrator would then decrease the speed and incline so the cool-down could then begin. When the speed and incline had been decreased, the

administrator would then remove the mouthpiece and nose clip. Cool-down consisted of 3-5 minutes at a comfortable walking pace. A research assistant recorded all of the summary data, including maximum heart rate, relative $\text{VO}_{2\text{max}}$, and $\text{VO}_{2\text{max}}$. The data was then transferred to electronic format, saved in Microsoft Excel, and stored by the PI on a University owned computer that was password protected.

Data Analysis

After the data was collected, the results were transferred to an Excel spreadsheet. The Statistical Package for the Social Sciences (SPSS) for Windows, version 18.0 was used for all statistical analysis. Levels of significance for all tests were set at $p < 0.05$.

Descriptive statistics were used for demographic data including gender, age, height, and weight. To answer research question one, related to the change in maximal oxygen uptake, a 2(time) X 2(gender) within-between ANOVA was used on the data. To answer research question two, related to the difference between returning cadets' and new cadets' maximal oxygen uptake, a 2(group) X 2(gender) ANOVA was conducted.

MANUSCRIPT

Physical training is important in the training of military cadets, including those enrolled in the Reserve Officers' Training Corps (ROTC) programs. The Reserve Officers' Training Corps program provides leadership and military training at schools and universities across the country (Roy, Springer, McNulty, & Butler, 2010). Participation in regular training and testing of physical fitness is required in order to ensure service members are optimally prepared to meet the physical demands of their missions (Foss & Keteyian, 1998). In the military, particularly ROTC programs, cardiovascular endurance and muscle endurance are most commonly measured, which is why regular physical training (PT) is often centered on these variables (Roy et al., 2010). For the purpose of this study, the focus will be on the cardiovascular endurance of the participants. Cardiovascular endurance reflects the ability of the lungs, blood, heart, muscles, and other organs and organ systems to transport and utilize oxygen, also referred to as maximum VO_2 ($\text{VO}_{2\text{max}}$) (Liguori & Carroll-Cobb, 2011). Measuring cardiovascular endurance helps not only to characterize an individual's ability to perform a certain task, but it can also be used to quantify the effect of a change in training regimen on performance (Foss & Keteyian, 1998).

Changes can occur in $\text{VO}_{2\text{max}}$ with both physical training and detraining (Midgley, McNaughton, & Wilkinson, 2006). Participating in different levels of exercise training can lead to increases in $\text{VO}_{2\text{max}}$. It is generally agreed upon that training completed with intensities between 40-80%, 3 days/week, for 30 minutes/day will elicit increases in an individuals' $\text{VO}_{2\text{max}}$ (Swain & Franklin, 2002; Midgeley et al., 2006; MacDougall & Sale, 1981; Mader, 1991; Wilmore & Costill, 2005). The amount of increase observed depends

on the initial fitness level of the individual, but generally around a 10% increase is seen (Wilmore & Costill, 2005). Cadets in the ROTC program are required to participate in mandatory physical training 3 days/week at similar training intensities. This would lead one to believe that increases would be seen in the cadets' $\text{VO}_{2\text{max}}$, however, research is lacking in this area. This is partly due to the fact that submaximal testing is done in the military to measure cardiovascular endurance, which is less accurate than maximal testing.

Detraining, which is when the amount of training an individual is accustomed to either decreases or stops completely, can have a negative impact on $\text{VO}_{2\text{max}}$ (Roy et al., 2010; Mujika & Padilla, 2000). The magnitude of the performance decline following a period of detraining appears to be related to initial fitness level, total time under reduced or absence of training stimuli, and whether the individual reduces their amount of training, or completely stops training (Mujika & Padilla, 2000). A study by Coyle et al. (1985) stated that highly trained athletes have been shown to decrease their maximal oxygen uptake by 6 to 14% during a training cessation of three to six weeks. However, Madsen, Pederson, Djurhuus, and Klitgaard (1993) reported that endurance capacity can vary considerably during detraining without changes in $\text{VO}_{2\text{max}}$.

Limited research has been conducted on the fitness levels of ROTC cadets and any effect (training or detraining) that a change in their training program may have on the cadets' cardiovascular endurance. Therefore the purpose of this study is two-fold: (1) to determine if $\text{VO}_{2\text{max}}$ changes over the summer in cadets when training is not mandatory and (2) to determine if there is a difference between returning cadets and new cadets' $\text{VO}_{2\text{max}}$.

Methods

Participants were recruited from all currently enrolled Tri-College ROTC cadets. Of 51 currently enrolled cadets, 49 completed all aspects of this study. Participants were asked to complete a graded exercise treadmill test in order to determine their maximal oxygen uptake. Testing was completed in the spring (T1) and then in the fall (T2) of 2010. Before the treadmill test began, the participant was equipped with a Polar® Accurex II heart rate monitor (Polar USA, Lake Success, NY) with the strap placed tightly across the chest. The individual's weight was then taken with a digital scale (Health O Meter model 751 KLS, Jarden Consumer Products, Boca Raton, FL) and height was measured with a Seca Road Rod 214 portable stadiometer (Seca GmbH & Co. KG, Hamburg, Germany). The information was then entered into the computer program, Breeze 6.2.055, which would eventually calculate the predicted $\text{VO}_{2\text{max}}$. The treadmill protocol was then explained in detail to the individual. The protocol used was a modified Taylor protocol that used 7 mph as the constant speed with the grade increasing one percent every minute (Taylor, et al., 1955). Duration of the warm-up was two minutes, during which time the participant ran at seven miles per hour at an even grade. During the test, the initial grade was set at zero; individuals maintained a 7 mph pace throughout the test while the incline was increased one percent every minute, with participants going until exhaustion. Once the participant had reached volitional fatigue, the administrator would then decrease the speed and incline so the cool-down could then begin, which consisted of 3-5 minutes at a comfortable walking pace. Summary data was then recorded which included maximum heart rate, relative VO_2 and $\text{VO}_{2\text{max}}$.

Statistical Analysis

Data were analyzed using the statistical package for the Social Sciences (SPSS) for Windows, version 18.0. Descriptive statistics were used to compute various demographic variables. In order to determine if maximal oxygen uptake changed over the summer in cadets when training was not mandatory, a 2(time) X 2 (gender) within-between ANOVA was used. Simple effects follow-up analysis was used to examine the time change trends for males and females separately. To evaluate whether changes in body composition influenced changes in absolute maximal oxygen uptake among returning cadets, an additional analysis was conducted while controlling for changes in body fat percentage.

To determine if at the start of the school year, there is a difference between returning cadets' and new cadets' absolute and relative maximal oxygen uptake, 2(group) X 2(gender) ANOVAs were conducted. To determine if differences in body fat percentage might be influenced by differences between groups or genders, an additional analysis was conducted while controlling for body fat percentage. Alpha was set $\leq .05$ for all analyses.

Results

A total of 49 out of 51 currently enrolled Tri-College ROTC cadets completed all aspects of the study (96.1%). The average age of the participants, including the returning cadets and the new cadets, was 21.56 ± 3.33 years. Basic descriptive data was calculated and is included in Table 1. Table 1 is regarding the first objective of the study and includes the returning cadets. The first objective was to determine if maximal oxygen uptake changed over the summer in cadets when training was not mandatory. Therefore, Table 1 is first divided by gender and then further divided by time point, referring to either the spring testing (T1) or the fall testing session (T2). Generally, the VO_{2max} of females is

approximately 15% to 25% below that of males; which is why each gender was analyzed separately (Foss & Keteyian, 1998).

Table 1. Descriptive Statistics for Participants

Time	Male		Female	
	T1	T2	T1	T2
	n = 24	n = 24	n = 8	n = 8
Weight	83.42 ± 11.06	84.03 ± 11.05	59.21 ± 6.15	59.23 ± 7.10
BF%	16.70 ± 5.87	15.53 ± 5.20	22.25 ± 4.55	18.71 ± 5.57*
Waist	87.20 ± 8.52	86.00 ± 7.19	73.85 ± 6.88	70.25 ± 5.01*
Max HR	195.58 ± 8.18	195.46 ± 8.44	191.50 ± 13.43	193.86 ± 5.37
VO ₂ (l/m)	4.47 ± 0.57	4.31 ± 0.48*	2.93 ± 0.36	2.71 ± 0.36
VO ₂ (ml/kg/min)	53.34 ± 5.68	51.07 ± 5.34*	48.64 ± 3.33	45.20 ± 2.01*

Note. *significant difference between T1 and T2, $p < 0.05$

In addition to calculating descriptive statistics, 2(time) X 2(gender) within-between ANOVAs were used to determine if maximal oxygen uptake changed over the summer in cadets when training was not mandatory. Significant decreases in absolute (Wilks = .79, $F(1, 30) = 7.81$, $p < .01$) and relative (Wilks = .69, $F(1, 30) = 13.82$, $p < .01$) VO_{2max} were found. Effect sizes for absolute ($\eta_p^2 = .21$) and relative ($\eta_p^2 = .32$) changes in maximal oxygen uptake across time were large which indicates that time had a substantial effect on the variability of VO_{2max} between the two time points. For both absolute ($F(1, 30) = 68.76$, $p < .001$) and relative ($F(1, 30) = 7.79$, $p < .01$) analyses, males had significantly higher maximal oxygen uptakes than females. No significant interactions were found for either the absolute or relative maximal oxygen uptake analyses. An additional 2 (time) X 2 (gender) within-between ANCOVA (controlling for body fat percentage change) did not change the results as significant decreases in absolute maximal oxygen uptake across time (Wilks = .83, $F(1, 29) = 6.07$, $p = .020$) and between genders remained ($F(1, 29) = 23.85$, $p < .001$), while the time by gender interaction remained non-significant.

Interestingly, simple effects follow-up contrasts revealed that the decrease in absolute maximal oxygen uptake was significant in males ($F(1, 30) = 5.41, p = .03$) while only approaching significance among females ($F(1, 30) = 3.55, p = .07$). However, when expressed relative to body mass, maximal oxygen uptake significantly decreased for both males ($F(1, 30) = 62.11, p < .01$) and females ($F(1, 30) = 47.3, p = .02$) from time point 1 (spring) to time point 2 (fall).

The second objective of the study was to determine if there was a difference between returning cadets' and new cadets' maximal oxygen uptake. Table 2 includes the descriptive statistics for both the returning cadets and the new cadets separated by gender. The returning cadets completed the testing in both the spring and the fall, whereas the new cadets were new students who were only able to complete the testing in the fall.

Table 2. Descriptive Statistics for Returning versus New Cadets

	Male		Female	
	R	N	R	N
	n = 24	n = 13	n = 8	n = 4
Age	21.08 ± 2.00	19.85 ± 2.38	21.38 ± 4.81	20.00 ± 2.71
Weight	84.03 ± 11.05	74.36 ± 8.06*	59.23 ± 7.10	61.19 ± 4.22
BF%	15.53 ± 5.20	11.73 ± 6.15*	18.71 ± 5.57	24.35 ± 5.09*
Waist	86.00 ± 7.19	79.23 ± 5.33*	70.25 ± 5.01	73.25 ± 5.92
Max HR	195.46 ± 8.44	195.92 ± 8.93	193.86 ± 5.37	194.75 ± 4.57
VO ₂ (l/m)	4.31 ± 0.48	3.91 ± 0.55	2.71 ± 0.36	2.82 ± 0.19
VO ₂ (ml/kg/min)	51.07 ± 5.34	52.02 ± 5.59	45.20 ± 2.01	45.70 ± 4.71

Note. *significant difference between new and returning cadets, $p < 0.05$

In addition to calculating descriptive statistics, a 2(group) X 2(gender) ANOVA was conducted to determine if at the start of the school year, there was a difference between returning cadets' and new cadets' maximal oxygen uptake. The F test, $F(1,45) = .17, p = .682$, associated with the group source (new or returning cadets) was not significant at the .05 level and no interaction effect was observed. The effect size was small, $\eta^2 = .004$. The

means for maximum VO_2 for the two groups were 48.86 ml/kg/mn for the new group of cadets and 48.13 ml/kg/mn for the returning cadets. Based on these results, a significant difference was not found between new and returning cadets' maximum VO_2 .

An ANCOVA was conducted in order to co-vary for body fat percentage. The difference in absolute $\text{VO}_{2\text{max}}$ scores was significant between genders; however the gender difference became non-significant for the relative analysis. The F test associated with gender was significant ($F(1, 45) = 12.01, p = .001$). The effect size was large, $\eta^2 = .21$. The means for maximum VO_2 for males and females were 51.54 and 45.45 respectively. The gender difference did, however, become non-significant for the relative analysis.

Discussion

The main objectives of this study were 1) to determine if maximal oxygen uptake ($\text{VO}_{2\text{max}}$) changed over the summer in cadets when training was not mandatory, and 2) to determine if there is a difference between returning cadets' and new cadets' $\text{VO}_{2\text{max}}$. Related to the first objective, the findings of the study showed that there was a significant decrease in the cadets' $\text{VO}_{2\text{max}}$ from time point 1 (spring) to time point 2 (fall). This difference suggests the possibility of a detraining effect. Detraining is when the amount of training an individual is accustomed to either decreases or stops completely (Mujika & Padilla, 2000). During the school year, the cadets participate in mandatory physical training three mornings per week. However, during the three summer months, training is not mandatory. The possibility exists that the cadets participate in less physical activity during the summer months, when physical training is not required, which could lead to a significant decrease in $\text{VO}_{2\text{max}}$. Similar to this study's results, previous studies have shown that the maximal oxygen uptake of individuals declines significantly during long-term

(more than four weeks) detraining (Mujika & Padilla, 2000; Coyle et al., 1985). However, Madsen, Pederson, Djurhuus, and Klitgaard (1993) reported that endurance capacity can vary considerably during detraining without changes in $\text{VO}_{2\text{max}}$. Training cessation results in larger declines in physiological and performance parameters when compared to a reduced training approach, therefore it is important to maintain some reduced training program during transition periods (Garcia-Pallares, Carrasco, Diaz, & Sanchez-Medina, 2009). Therefore it would most likely be beneficial if some sort of physical training was required of the cadets over the summer months; this could lead to less of a decrease in $\text{VO}_{2\text{max}}$.

The study also investigated the difference between returning cadets' and new cadets' $\text{VO}_{2\text{max}}$. Findings from this study indicate that there is not a significant difference in maximal oxygen uptake between the returning cadets and the new cadets in either males or females. Prior to the summer months, the returning cadets had been participating regularly in mandatory physical training, whereas the new cadets had not. Studies have shown that training leads to increases in $\text{VO}_{2\text{max}}$ (Swain & Franklin, 2002; Midgeley et al., 2006; MacDougall & Sale, 1981; Mader, 1991; Wilmore & Costill, 2005). Therefore, an assumption could be made that the returning cadets would have a higher $\text{VO}_{2\text{max}}$ than the new cadets. However, it is possible that the new, incoming cadets anticipated the type of physical training they would be participating in which could have led them to begin more vigorous training on their own during the summer months in preparation, or 'anticipatory' training. Conversely, the returning cadets may have felt more comfortable with the training expectations, and therefore felt less need to maintain fitness throughout the summer, resulting in a similar $\text{VO}_{2\text{max}}$ value between groups. A significant difference in $\text{VO}_{2\text{max}}$ was

seen between genders, however, which is in agreement with findings from past studies. Generally, the $\text{VO}_{2\text{max}}$ of females is below that of males (Foss & Keteyian, 1998; McArdle, Katch, & Katch, 2005). Reasons for this are likely threefold; females have more essential body fat than males, the hemoglobin concentration of females is about 5% to 20% lower than in males, and physical activity levels differ between genders (Foss & Keteyian, 1998).

In summary, this study found that over a three month break from mandatory physical training, a significant decrease in $\text{VO}_{2\text{max}}$ was seen for both male and female ROTC cadets. This information could be applied by providing the cadets with a physical training program to be completed during extended breaks, in order to maintain or possibly improve cardiovascular endurance. While no difference was noted between returning cadets' and new cadets' $\text{VO}_{2\text{max}}$, this could be an artifact of detraining by returning cadets just as much as 'anticipatory' training on the part of new cadets. Lastly, as to be expected, there was a significant difference in $\text{VO}_{2\text{max}}$ between genders. More research on the effect of detraining in ROTC cadets is still needed. Future studies should include larger sample sizes and more of an equal representation of females and males. In addition, longitudinal studies that evaluate the differences in $\text{VO}_{2\text{max}}$ over a longer period of time may be of considerable value.

References

- Foss, M. L. & Keteyian, S. J. (1998). *Physiological Basis for exercise and Sport* (6th Ed.). New York, NY: WCB McGraw-Hill.
- Garcia-Pallares, J., Carrasco, L., Diaz, A., & Sanchez-Medina. (2009). Post-season detraining effects on physiological and performance parameters in top-level kayakers: comparison of two recovery strategies. *Journal of Sports Science and*

Medicine, 8, 622-628.

Liguori, G. & Carroll-Cobb, S. (2011). *Fitwell: Questions and Answers*. New York, NY: McGraw-Hill.

Mader, A. (1991). Evaluation of the endurance performance of marathon runners and theoretical analysis of test results. *Journal of Sports Medicine and Physical Fitness*, 31, 1-19.

Madsen, K., Pedersen, P. K., Djurhuus, M. S., & Klitgaard, N. A. (1993). Effects of detraining on endurance capacity and metabolic changes during prolonged exhaustive exercise. *Journal of Applied Physiology*, 75(4), 1444-1451.

MacDougall, D. & Sale, D. (1981). Continuous vs interval training: a review for the athlete and the coach. *Canadian Journal of Applied Sport and Science*, 6, 93-97.

McArdle, D. W., Katch, F. I., & Katch, V. L. (2005). *Essentials of Exercise Physiology* (2nd Ed). New York, NY: Lippincott Williams & Wilkins.

Midgley, A. W., McNaughton, L. R., & Wilkinson, M. (2006). Is there an optimal training intensity for enhancing the maximal oxygen uptake of distance runners? *Sports Medicine*, 36(2), 117-132.

Mujika, I. & Padilla, S. (2000). Detraining: Loss of training-induced physiological and performance adaptations. *Sports Medicine*, 30(3), 145-154.

Roy, T. C., Springer, B. A., McNulty, V., & Butler N. L. (2010). Physical fitness. *Military Medicine*, 175(8), 14-20.

Swain, D. P. & Franklin, B. A. (2002). VO₂ reserve and the minimal intensity for improving cardiorespiratory fitness. *Medicine and Science in Sports and Exercise*, 35, 152-157.

Taylor, H. L., Kuskirk, E., & Henschel, A. (1955). Maximal oxygen intake as an objective

measure of cardio-respiratory performance. *Journal of Applied Physiology*, 8, 73-80.

Wilmore, J. H. & Costill, D. L. (2005). *Physiology of Sport and Exercise* (3rd Ed.). Champaign, IL: Human Kinetics.

REFERENCES CITED

- American College of Sports Medicine. (2006). *ACSM's Guidelines for Exercise Testing and Prescription* (7th ed.). Philadelphia, PA: Lippincott Williams & Wilkins.
- Astrand, P. & Ryhming, I. (1954). A nomogram for calculation of aerobic capacity (physical fitness) from pulse rate during submaximal work. *Journal of Applied Physiology*, 7, 218-221.
- Bassett, D. R. & Howley, E. T. (2000). Limiting factors for maximum oxygen uptake and determinants of endurance performance. *Medicine and Science in Sports and Exercise*, 32, 70-84.
- Berthouze, S. E., Minaire, P. M., Castells, J., Busso, T., Vico, L., & Lacour, J. (1995). Relationship between mean habitual daily energy expenditure and maximal oxygen uptake. *Medicine and Science in Sports and Exercise*, 27(8), 1170-1179.
- Blacker, S. D., Wilkinson, D. M., & Rayson, M. P. (2009). Gender differences in the physical demands of British Army recruit training. *Military Medicine*, 174(8), 811-816.
- Bruce, R. A., Kusumi, F., & Hosmer, D. (1973). Maximal oxygen intake and nomographic assessment of functional aerobic impairment in cardiovascular disease. *American Heart Journal*, 85, 546-562.
- Coyle, E. F., Martin, W. H., Bloomfield, S. A., Lowry, O. H., & Holloszy, J. O. (1985). Effects of detraining on responses to submaximal exercise. *Journal of Applied Physiology*, 59(3), 853-859.
- Foss, M. L. & Keteyian, S. J. (1998). *Physiological Basis for exercise and Sport* (6th Ed.). New York, NY: WCB McGraw-Hill.

- Garcia-Pallares, J., Carrasco, L., Diaz, A., & Sanchez-Medina. (2009). Post-season detraining effects on physiological and performance parameters in top-level kayakers: comparison of two recovery strategies. *Journal of Sports Science and Medicine*, 8, 622-628.
- George, J. D. (1996). Alternative approach to maximal exercise testing and VO_{2max} prediction in college students. *Research Quarterly for Exercise and Sport*, 67, 452-457.
- George, J. D., Bradshaw, D. I., Hyde, A., Vehrs, P. R., & Hager, R. L. (2007). A maximal graded exercise test to accurately predict VO_{2max} in 18-65-year-old adults. *Measurement in Physical Education and Exercise Science*, 11(3), 149-160.
- George, J. D., Vehrs, P. R., Allsen, P. E., Fellingham, G. W., & Fisher, A. G. (1993). VO_{2max} estimation from a submaximal 1-mile track jog for fit college-age individuals. *Medicine & Science in Sports & Exercise*, 25(3), 401-406.
- Jette, M., Campbell, J., Mongeon, J., & Routhier, R. (1976). The Canadian home fitness test. *Canadian Medical Association Journal*, 114, 680-683.
- Kline, G. M., Porcari, J. P., Hintermeister, R., Freedson, P. S., Ward, A., Mccaron, R. F., et al (1987). Estimation of VO_{2max} from a one-mile track walk, gender, age, and body weight. *Medicine and Science in Sports and Exercise*, 19, 252-259.
- Knapik, J. (1989). The Army Physical Fitness Test (APFT): a review of literature. *Military Medicine*, 154(6), 326-329.
- Liguori, G. & Carroll-Cobb, S. (2011). *Fitwell: Questions and Answers*. New York, NY: McGraw-Hill.
- MacDougall, D. & Sale, D. (1981). Continuous vs interval training: a review for the athlete and the coach. *Canadian Journal of Applied Sport and Science*, 6, 93-97.

- Mader, A. (1991). Evaluation of the endurance performance of marathon runners and theoretical analysis of test results. *Journal of Sports Medicine and Physical Fitness*, 31, 1-19.
- Madsen, K., Pedersen, P. K., Djurhuus, M. S., & Klitgaard, N. A. (1993). Effects of detraining on endurance capacity and metabolic changes during prolonged exhaustive exercise. *Journal of Applied Physiology*, 75(4), 1444-1451.
- Matti, S., Hakkinen, K., Karavirta, L., & Kyrolainen, H. (2008). Changes in cardiovascular performance during an 8-week military basic training period combined with added endurance or strength training. *Military Medicine*, 173(12), 1173-1179.
- McArdle, D. W., Katch, F. I., & Katch, V. L. (2005). *Essentials of Exercise Physiology* (2nd Ed). New York, NY: Lippincott Williams & Wilkins.
- Melanson, E. L. & Freedson, P. S. (1996). Physical activity assessment: A review of methods. *Critical Reviews in Food Science and Nutrition*, 36, 385-396.
- Mello, R. P., Murphy, M. M., & Vogel, J. A. (1988). Relationship between a two mile run for time and maximal oxygen uptake. *Journal of Applied Sport & Science*, 2(1), 9-12.
- Midgley, A. W., McNaughton, L. R., Polman, R., & Marchant, D. (2007). Criteria for determination of maximal oxygen uptake. *Sports Medicine*, 37(12), 1019-1028.
- Midgley, A. W., McNaughton, L. R., & Wilkinson, M. (2006). Is there an optimal training intensity for enhancing the maximal oxygen uptake of distance runners? *Sports Medicine*, 36(2), 117-132.
- Mujika, I. & Padilla, S. (2000). Detraining: Loss of training-induced physiological and performance adaptations. *Sports Medicine*, 30(3), 145-154.
- Physical Fitness Training: Army Field Manual (FM) 21-20. (1992). Washington, DC, Headquarters, Department of the Army.

- Pollock, M. L. (1973). Quantification of endurance training programs. *Exercise and Sport Sciences Reviews*, 1, 155-188.
- Roy, T. C., Springer, B. A., McNulty, V., & Butler N. L. (2010). Physical fitness. *Military Medicine*, 175(8), 14-20.
- Schoeller, D. A. (1988). Measurement of energy expenditure in free-living humans by using doubly labeled water. *Journal of Nutrition*, 118(11), 1278-1289.
- Spackman, M. B., George, J. D., Pennington, T. R., & Fellingham, G. W. (2001). Maximal graded exercise test protocol preferences of relatively fit college students. *Measurement in Physical Education & Exercise Science*, 5, 1-12.
- Swain, D. P. & Franklin, B. A. (2002). VO_2 reserve and the minimal intensity for improving cardiorespiratory fitness. *Medicine and Science in Sports and Exercise*, 35, 152-157.
- Taylor, H. L., Kuskirk, E., & Henschel, A. (1955). Maximal oxygen intake as an objective measure of cardio-respiratory performance. *Journal of Applied Physiology*, 8, 73-80.
- U.S. Department of Health and Human Services (2008). *2008 Physical Activity Guidelines for Americans*. Washington, DC: DHHS.
- Vanderburgh, P. M. (2007). Correction factors for body mass bias in military fitness tests. *Military Medicine*, 172(7), 738-742.
- Vanhees, L., Lefevre, J., Philippaerts, R., Martens, M., Huygens, W., Troosters, T., et al. (2005). How to assess physical activity? How to assess physical fitness? *European Journal of Cardiovascular Prevention and Rehabilitation*, 12, 102-114.
- Wilmore, J. H. & Costill, D. L. (2005). *Physiology of Sport and Exercise* (3rd Ed.). Champaign, IL: Human Kinetics.