INFLUENCE OF TRAINING STATUS ON HUMAN PERFORMANCE AND PHYSICAL CHARACTERISTICS AMONG CIVILIAN AND RESERVE OFFICERS' TRAINING CORPS POPULATIONS

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INFLUENCE OF TRAINING STATUS ON HUMAN PERFORMANCE AND PHYSICAL CHARACTERISTICS AMONG CIVILIAN AND RESERVE OFFICERS' TRAINING CORPS POPULATIONS

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The primary objective of this investigation was to examine the influence of training status on human performance and physical characteristics among civilian and ROTC. Study 1 was designed to determine if maximal and rapid force characteristics as well as fatigue responses of the knee extensors and flexors could discriminate between two different types of training among men. The evidence from that investigation seems to support the idea that resistance-trained individuals may react similarly when put through a fatiguing bout of dynamic isokinetic exercise. Study 2 examined the effects of differing back squat exercises on the acute recovery responses of maximal velocity and acceleration of the knee extensors. This study revealed that both acceleration and maximal velocity may be negatively affected following exercise for up to 30-minutes post-exercise. Study 3 examined the immediate and acute recovery performance responses after performing two different back squat exercise protocols on vertical jump performance in women. The primary finding of study 3 was the immediate decrease in power, velocity, and jump height along with these variables being further decreased following the entire exercise protocol. Study 4 sought to determine if fatiguing, moderate-velocity muscle actions affect isokinetic strength characteristics to a greater extent compared to their isometric strength counterparts. The primary finding of that investigation was the significant differential acute responses between isometric and isokinetic peak torque fatigue indices. Study 5 examined ROTC cadets over a four-year period. The primary finding of that investigation was a lack of improvement in most of the variables measured during the longitudinal assessment and the absence of differences between class ranks. Study 6 was designed to determine if significant changes in cadet physical performance occur after summer break when training is not mandatory. The primary findings of this investigation were that significant reductions in performance on the fitness assessment occurred following summer break. Study 7 is designed to examine the physical fitness profile of ROTC cadets and U.S. military veterans and is currently ongoing. Preliminary results indicate cadets rank in the top 50th and veterans rank in the lower 50th percentile for most of ACSM’s physical fitness evaluations.

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CHAPTER I

INTRODUCTION

Physical training has been shown to elicit several essential benefits related to human performance, including but not limited to cardiovascular fitness, muscular hypertrophy, increased strength, power, and speed (Hooper et al., 2013). Manipulation of training characteristics (i.e., number of sets, repetitions, length of rest periods, and external load) may produce differential adaptive responses in skeletal muscle, as it may be sensitive to the acute and chronic stressors associated with training. These responses are influenced by the structure and implementation of the physical activity, as well as the level of training (i.e., beginner, intermediate, or advanced) for the individuals involved (Abernethy et al., 1994). Consequently, there appears to be a specific relationship between modes of training (i.e., muscular strength, power, and endurance) and the adaptive response (Campos et al., 2002). While training programs are certainly intended to improve specific variables (strength, endurance, speed, agility, lean body mass) over the course of various training blocks (meso, macro, micro cycles), understanding responses to various bouts of training/exercises may help guide alterations to the programs being utilized.

Complex processes associated with brief bouts of exercise and muscular contractions (dynamic or otherwise) may lead to differences in ensuing performance responses. This may primarily depend upon the characteristics of muscle action/activation strategy or influences of task familiarity, resulting in enhanced muscular performance (postactivation potentiation), or deficits to any related performance characteristics (fatigue) (Tillin and Bishop, 2009). Fatigue has been defined as any reduction in the force-producing capacity of a muscle during a maximal voluntary contraction (Gandevia, 1992), as well as an inability to maintain a given, maximal strength level, when performing repeated maximal dynamic contractions (Mathiassen, 1989). This reduction in force-producing capacity may lead to deficits in subsequent muscular performance, thus hindering physical ability post-exercise. Knowing this, the effects of dynamic fatiguing protocols may result in acute deficits in maximal strength and rapid force characteristics of the lower and upper extremity in both sedentary and trained individuals. Consequently, the ability to identify significant differences in strength and rapid force characteristics between dissimilarly trained groups following dynamic fatiguing protocols, may lead to further understanding of specific acquired adaptations to training and acute recovery responses. Additionally, while decreases in performance may occur post-fatigue, considerable evidence suggests that fatigue is not caused by a single factor, and, that the mechanisms underlying the force reduction are task specific (Enoka, 1992; Gandevia, 2001). For instance, a significant amount of research has been conducted on dynamic fatiguing protocols and acute recovery responses (pre vs. post isometric assessment) (Conchola et al., 2015; Chiu et al., 2004; Klass et al., 2004; Marshall et al., 2012; Walker et al., 2012), however, discrepancies in acute responses from fatigue could be related to the different fatigue interventions that were implemented (overall percent fatigue, repetition scheme, time under tension, etc.). Thus, assessing multiple modalities may provide different results and may provide more answers about the mechanisms regarding fatigue responses.

Physical fitness is important for general health and physically performing acts of daily living and occupational tasks. Physical fitness can be briefly defined as, “a set of attributes that relate to the ability of people to perform physical activity” (McArdle et al., 1991). By this definition, physical fitness is not a single characteristic but has a number of attributes or components. In the military services, higher levels of physical fitness are vital for limiting modifiable risk-factors, improving military task-specific performance, and injury prevention (Knapik et al., 2018). Thus, sufficient levels of physical fitness are emphasized in military personnel due to the high physical demands during military training and in warfare (Knapik et al., 1990).

In a military context, the term “physical fitness” is predominantly identified as muscular strength, muscular endurance, cardio-respiratory endurance, and body composition (Knapik et al., 2006). This is evidenced by current the fitness assessments used by the U.S. military for retention in service. For example, the U.S. Army and Air Force physical fitness test/assessment consists of timed push-ups, timed sit-ups, body composition (body mass index or abdominal circumference) and a 2-mile or 1.5 mile run (U.S. Department of the Army 2013; Department of the Air Force 2013). While these fitness tests are meant to measure active duty military members physical conditioning through cardiorespiratory fitness, muscular endurance, and body composition, muscular strength and flexibility, which are considered basic components of physical fitness, are not measured (American College of Sports Medicine, 2018). Consequently, the inclusion of muscular strength and flexibility components to the U.S. military physical fitness tests/assessments may aid in a more comprehensive physical fitness measurement and provide a more detailed physical fitness profile of our servicemembers.

The U.S. Reserve Officers' Training Corps (ROTC) programs are designed to recruit, educate and commission officer candidates through college campus programs based on U.S. armed forces requirements. It prepares the cadets to become U.S. officers while earning a college degree. At this time, the ROTC acts as the largest commissioning source among all military branches and ROTC programs are offered at numerous colleges and universities across the U.S. One role of ROTC programs is to physically prepare cadets for the demands of a military career. As a result, an important element of the ROTC experience is physical training (PT), which is meant to enhance physical fitness, develop discipline, and provide a unifying experience (Thomas et al., 2004). Specifically, physical training is incorporated as a part of the military culture to establish an environment for members to maintain physical fitness and health to meet expeditionary mission requirements.

Currently, ROTC cadets are required to participate in PT two to three times per week depending on the branch of service and detachment they are located at and at least 80 percent attendance is mandatory in order to pass their leadership laboratory course. However, this mandatory PT only takes place during the fall and spring semesters. This means that cadets are without a structured/mandatory PT program over the summer period (~3 months) and could be susceptible to detraining. Recent studies involving ROTC cadets have examined the effects of training interventions (Gist et al., 2015;

Schiotz et al., 1998), effect of time in ROTC on physical assessments (Crombie et al., 2012; Oliver et al., 2017), body composition and its relation to the fitness assessments (Jones et al., 2012; Steed et al., 2016), or fitness profiling (Thomas et al., 2004). These studies have provided valuable insight and a greater understanding of the ROTC cadet's physical fitness, however, in terms of how they compare to their civilian and veteran counterparts, unanswered questions still remain. In addition, the last (and potentially only) physical fitness profile of ROTC cadets was done almost 16 years ago (Thomas et al., 2004). Updating our current knowledge of ROTC cadets' physical fitness and comparing them to other populations (e.g., civilians and veterans) may provide an increased understanding of the potential benefits or consequences of participating in the ROTC program and how well it prepares them for the physical demands of active duty service.

Military veterans represent a unique group, who through their military experience, have been exposed to a multitude of individual, social, psychological, and physical stressors (Haibach et al., 2016). At this time, there are more than 18 million living veterans residing in the U.S. Due to formal physical training and weight standards during military service, one might expect a lower prevalence of overweight, obesity, and other health risk factors among veterans compared to nonveterans. However, while military recruits and servicemembers are healthier than the civilians/nonveterans due to the aforementioned screening requirements and fitness standards, many veterans become insufficiently active and develop health problems soon after discharge from the military (Goodrich & Hall, 2017; Haibach et al., 2016). In addition, recent life-course trends indicate a surge of weight gain following military separation among younger veterans (Koepsell et al., 2012; Littman et al., 2013; Rosenberger et al., 2011).

Research examining the relationship between veterans and physical activity have reported mixed findings, and differ by the mode of activity assessed, type of measures used, and characteristics of the population. For example, studies utilizing self-report measures of physical activity, the prevalence of those meeting physical activity recommendations was higher (inactivity was lower) in veterans compared to nonveterans (Hoerster et al., 2015; Littman et al., 2009). However, in studies implementing objective assessments (accelerometers) of physical activity, no significant differences were found between veterans and nonveterans, but the amount of inactivity was higher in veterans (Littman et al., 2013). Considering physical activity across assessment methods, evidence suggests that physical activity is low among veterans (Hoerster et al., 2015; Littman et al., 2009; Littman et al., 2013). Although much research has been done investigating the prevalence of obesity and physical activity of veterans residing in the U.S., the majority of the studies identified relied on self-reported (survey based) rather than objective data. Additionally, there appears to be a paucity of literature regarding the overall physical fitness levels, with the exception of body composition (majority of studies report body mass index), of U.S. military veterans. Identifying the fitness levels of veterans may provide key information in regard to their health status along with indicating where veterans rank against the civilian population and pre-military personnel (i.e., ROTC). Examining and comparing the overall physical fitness of veterans to civilians, and ROTC cadets may help shed more light on the differences between these populations and the toll military service takes on the human body.

CHAPTER II

MANUSCRIPTS

2.1. Mackey, C.S., Thiele, R.M, Conchola, E.C., and DeFreitas, J.M. (2018). Comparison of fatigue responses and rapid force characteristics between explosive- and traditional-resistance trained males. *European Journal of Applied Physiology*. 118, 1539-1546.

2.1.1. Introduction

Resistance-training has been shown to elicit several essential benefits related to human performance, including, but not limited to, muscular hypertrophy, increased strength, power, and speed (Hooper et al. 2013). Manipulation of resistance-training programming characteristics (i.e., number of sets, repetitions, movement velocity, length of rest periods, and external load) has been shown to produce differential adaptive responses in skeletal muscle specific to the various acute and chronic stressors (Campos et al. 2002; Jones and Rutherford 1987; Mangine et al. 2008; Schuenke et al. 2012; Winchester et al. 2008). These responses have been shown to be influenced by the structure and implementation of resistance activity, as well as the training status (i.e., beginner, intermediate, or advanced) of the individuals involved (Abernethy et al. 1994).

Although resistance-training can serve many purposes, it is suggested that the *specificity principle* may allow for optimal performance. This principle recommends that the exercise prescription should be designed to be similar to the athletic movements that would be performed by the individual (Hansen 1961; Hansen 1963; Murray et al. 2007; Pereira and Gomes 2003; Rasch and Morehouse 1957). Recent examinations showed that the greatest gains in force and power production are seen at movement velocities comparable to that of training (Murray et al. 2007; Pereira and Gomes 2003). This is further demonstrated by Behm (1995), who revealed, in order to maintain high velocity specific adaptations in a power training program, the speed of contraction must be high/fast ($\geq 240^{\circ} \cdot s^{-1}$) (Murray et al. 2007; Pereira and Gomes 2003). While exercise prescription can have direct effects on performance, studies with younger adults have shown differential responses with the development of muscle power and rapid force generation when comparing explosive (ERT) versus heavy resistance-training (Caserotti et al. 2008; Newton et al. 1999). For example, Newton et al. (1999) found significant increases in vertical jump ability when performing explosive based movements compared to traditional resistance-training (TRT). Although power has been shown to increase with TRT (Channell and Barfield 2008; Jozsi et al. 1999), the specificity of ERT may have a greater influence on the ability to apply force rapidly. For example, TRT tends to focus on higher intensities at lower-speeds (Channell and Barfield 2008), whereas ERT can be defined as movements (e.g., snatch, hang clean, power clean, and push jerk) in which maximum or near maximum rates of force development are attained (Stone and O'Bryant 1987).

Previous authors have attempted to understand specific training adaptations related to increases in strength and power production (Fielding et al. 2002; Judge et al. 2003). For example, Fielding et al. (2002) found that a ERT program significantly improved peak power, and was equally efficient at increasing muscle strength compared to TRT. In addition to prior training studies, previous authors have assessed neuromuscular differences between individuals with different training backgrounds (Häkkinen and Keskinen 1989; Lattier et al. 2003). Recently, a trend in ERT has incorporated workouts consisting of power movements in combination with other varied functional movements performed at high intensity or to failure (Bergeron et al. 2011; Hak et al. 2013; Smith et al. 2013). Smith et al. (2013) labeled this type of training as high-intensity power training which focused on sustained power output and use of multiple joint movements without a prescribed rest period. While previous literature suggests specific muscular adaptations occur following resistance-training interventions such as increased maximal force (Newton et al. 2002), power (Murray et al. 2007; Newton et al. 2002), hypertrophy (McCaulley et al. 2009; Schuenke et al. 2012), increases in Type II fibers (Schuenke et al. 2012), and initial training statuses (sedentary vs. trained) (Alway et al. 1988; Newton et al. 2008), it may be informative to assess specific rapid force characteristics and fatigue-induced responses of maximal strength between different resistance-trained groups to further elucidate these muscular adaptations related to specificity of training.

Due to the training specificity and the aforementioned observed training adaptations of TRT and ERT, it may be of interest to examine the potential differences in fatigue-induced responses to performance measures, (e.g., maximal strength), between two resistance-trained groups. Specifically, fatigue has been defined as any reduction in the force-producing capacity of a muscle during a maximal voluntary contraction (Gandevia 1992), as well as an inability to maintain a given maximal strength level when performing repeated maximal contractions (Mathiassen 1989). This reduction in force-producing capacity may lead to deficits in subsequent muscular performance, thus hindering physical ability post-exercise.

Although a majority of muscle fatigue literature is based upon the use of intermittent and/or sustained isometric contractions (Bilodeau et al. 2001; Conchola et al. 2015; Conchola et al. 2013; Corcos et al. 2002; Pääsuke et al. 1999), the nature of most motor tasks in athletic and voluntary physical activities may lend itself, rather, to the assessment of dynamic muscle contractions (Izquierdo et al. 2009; Wadden et al. 2012). Thus, the ability to identify significant differences in strength and rapid force characteristics between two dissimilarly trained groups following a dynamic fatigue protocol, may lead to further understanding of specific acquired adaptations to training. Therefore, the purpose of this study was to compare the rapid force characteristics and dynamic fatigability between ERT and TRT resistance-trained men. We hypothesized that the ERT group would display greater absolute rapid force characteristics and fatigue resistance, but lower strength when compared to the TRT group.

2.1.2. Methods

Participants

Fourteen traditional resistance-trained (TRT) (mean ± SD: age = 24.79 ± 3.12 years, height = 179.86 ± 6.25 cm, mass = 94.29 ± 14.15 kg) and twelve explosive resistance-trained (ERT) (mean ± SD: age = 21.83 ± 1.90 years, height = 176.74 ± 5.88 cm, mass = 85.47 ± 11.57 kg) males volunteered to participate in this study. All participants reported being consistently engaged in a structured TRT (mean ± SD: 6.26 ± 3.31 years) or ERT (mean ± SD: 4.92 ± 2.80 years) resistance-training program for a minimum of 6 months, ≥3 times per week, prior to the study. Participants who reported their workouts as a combination of strength (≤6 repetitions at ≥85% 1RM) and hypertrophy (6-12 repetitions at 67-85% 1RM) movements (i.e., back squat, bench press, deadlift, bent over row, and shoulder press) were identified as TRT. Participants who reported workouts consisting of power movements (i.e., snatch, hang clean, power clean, and push jerk) with a goal of 1-2 repetitions for a single-effort (80-90% 1RM) or 3-5 repetitions for multiple effort (75-85% 1RM) events in combination with other varied functional movements performed at high intensity or to failure were identified as ERT. No participants reported current or ongoing musculoskeletal injuries of the lower extremity within the previous 12 months prior to testing. The University Institutional Review Board for human subject’s research approved this study, and each participant signed an informed consent document and pre-exercise health history questionnaire before testing began.

Procedures

This was a descriptive study to investigate group differences in strength, rate of torque development (RTD), velocity (V_{max}), acceleration (ACC_{max}), and fatigability of the knee flexors (KF) and extensors (KE). Each participant visited the laboratory on 2 occasions separated by ~48-72 hours. During the first visit, participants were familiarized with isometric and isokinetic maximal voluntary contractions (MVCs), as well as the experimental fatigue protocol. During the second visit, participants completed isokinetic and isometric MVCs of the KF and KE prior to 50 isokinetic muscle actions of both muscle groups at 180°·s^{-1} (Thorstensson and Karlsson 1976).

Isometric RTD Assessments

Maximal isometric rapid strength testing was performed on the right leg using a Biodex System 3 isokinetic dynamometer (Biodex Medical Systems, Inc., Shirley, NY, USA). Participants were seated with restraining straps over the trunk, pelvis, and thigh, with the input axis of the dynamometer aligned with the axis of rotation of the knee. All isometric RTD assessments for the KE and KF were performed at knee angles of 120° and 150°, respectively (full extension = 180°). Prior to maximal isometric rapid strength testing, participants performed a 5-minute warm-up on a cycle ergometer (Monark Exercise 828E, Vansbro, Sweden) at a self-selected low-intensity. In addition, 3 submaximal isokinetic muscle actions were performed at 60°·s^{-1} at approximately 75% of their perceived maximal effort for both the KE and KF. Following the submaximal contractions and prior to experimental testing, each participant performed 3 isometric MVCs of the KE and KF with 1 minute of recovery between each contraction. The participants were verbally instructed to 'push' or 'pull,' "as hard and fast as possible" for a total of 3-4 seconds for all MVCs (Thompson et al. 2013).

Isokinetic Velocity Assessments

Similar to the aforementioned maximal isometric testing procedures, maximal isokinetic velocity (V_{max}) testing was performed on the right leg using the isokinetic dynamometer, in isokinetic mode at 500°·s^{-1}. All isokinetic assessments started at knee angles of 90º and ~180º (full extension) for the KE and KF, respectively. Each participant performed 3 isokinetic MVCs through ~90º of range of motion (ROM) for the KE and KF with 1 minute of recovery between each contraction. V_{max} was used to assess the maximal shortening velocity of the muscle-limb unit in which no resistance (with the exception of the lever arm) was provided throughout the duration of the contraction (i.e. velocity of the dynamometer was set above all subjects' maximum velocity capacities), in accordance with the procedures of Thompson et al. (2014) . The participants were verbally instructed to 'push' or 'pull,' "as fast as possible".

Experimental Fatigue Protocol

Five minutes following all Pre MVCs, participants performed the fatigue protocol consisting of 50 continuous repetitions of dynamic isokinetic contractions of the KE and KF at $180^{\circ}\cdot s^{-1}$ (medium velocity) through ~90º ROM (Thorstensson and Karlsson 1976). Participants were seated with restraining straps across the trunk, pelvis, and thigh identical to all MVC testing procedures. Additionally, participants started the protocol with their right limb at a resting knee angle of 90º, and their lower limb secured to the dynamometer lever arm, just above the ankle. During the experimental protocol, participants were asked to provide maximal effort for each muscle action and to 'push' or 'pull', as hard as they can throughout the entire protocol. Experimental testing was terminated at the completion of all 50 maximal repetitions. Verbal encouragement was provided to the participants during the entire protocol.

Signal Processing

Torque (N·m), rate of torque development (RTD; N·m·s^{-1}), and angular velocity (deg·s^{-1}) signals were sampled simultaneously at 2 kHz with a Biopac data acquisition system (MP100WSW, Biopac Systems, Inc.; Santa Barbara, CA, USA), stored on a personal computer (Dell Inspiron 8200, Dell Inc., Round Rock, TX, USA), and processed off-line with custom-written software (LabVIEW version 16.0, National Instruments, Austin, TX, USA). The torque signal was smoothed using a 25ms zero-shift moving average. All subsequent analyses were performed on the scaled and filtered torque signal. Isometric MVC PT was determined as the highest 25ms epoch during the entire 3–4 s MVC plateau (Conchola et al. 2013; Thompson et al. 2013). Absolute RTD was calculated from the linear slope of the torque-time curve (Δvelocity/Δtime) over the interval of 0-50ms (RTD_{0-50}). Isokinetic PT was attained from the first and last few repetitions of the fatigue protocol. V_{max} (deg·s^{-1}) was calculated as the highest velocity attained during the unloaded MVC. Acceleration (ACC_{max}; deg·s^{-2}) was determined as the 10ms that demonstrated the highest linear slope of the velocity-time curve (Δvelocity/Δtime). These procedures were used to obtain the linear portion of the rate of rise in velocity, while simultaneously excluding the deceleration or "rounding off" of the signal observed at the edge of the velocity plateau. The onset of velocity was determined as the point when the velocity signal reached a threshold 2 deg·s^{-1} above baseline. The MVC with the highest PT, RTD_{0-50}, V_{max}, and ACC_{max} prior to the experimental protocol were used for all analyses (Thompson et al. 2014). Isokinetic 180°·s^{-1} FI% was calculated using initial and final PT which consisted of the average of the three muscle actions with the highest and lowest PT values during the fatigue protocol. All fatigue indices were calculated as “(Final – Initial) ÷ Initial × 100” (Thorstensson and Karlsson 1976).

Statistical Analysis

Independent samples t-tests were run for the KE and KF between groups (traditional vs. explosive) for each dependent variable (isokinetic PT, isokinetic FI%, isometric $RTD_{0\text{-}50}$, V_{max}, and ACC_{max}). Cohen’s d effect sizes and 95% confidence intervals were run for the KF and KE for each dependent variable assessed for the TRT and ERT groups. PASW software version 23.0 (SPSS Inc, Chicago, IL, USA) was used for all statistical analyses. An alpha level of $p \leq 0.05$ was considered significant for all comparisons.

2.1.3. Results

Means and *SD* values for all dependent variables are presented in Table 1, and the effect sizes are shown in Figure 1. The ERT group (M ± *SD*; 1199.05 ± 404.12) displayed a significantly higher baseline (absolute) isometric $RTD_{0\text{-}50}$ ($p = 0.049$) for the KE compared to the TRT group (931.73 ± 244.75) (Figure 2). No other significant differences were observed between groups (TRT vs. ERT) for either of the muscle groups (KE and KF) and the dependent variables (isokinetic PT, isokinetic FI%, V_{max}, ACC_{max}; $p \geq 0.05$).

Table 1. Mean ± *SD* of the knee extensors (KE) and flexors (KF) from the explosive (ERT) and traditional (TRT) resistance-trained groups for each variable: isokinetic peak torque (PT; N·m), isokinetic PT fatigue index (FI%), rate of torque development (RTD; N·m·s^{-1}), peak acceleration (ACC_{max}, deg·s^{-2}), and peak velocity (V_{max}, deg·s^{-1}). All values presented were recorded prior to the experimental fatigue protocol with the exception of iskokinetic PT for the FI% calculation.

Muscle Group	Training Group	Isokinetic PT	Isokinetic PT FI%	RTD_{0-50}	ACC_{max}	V_{max}
KE	ERT	158.47 ± 30.76	-50.49 ± 10.58	*1199.05 ± 404.12	4263.16 ± 505.23	479.66 ± 14.73
	TRT	168.40 ± 33.40	-57.98 ± 12.05	931.73 ± 244.75	4319.87 ± 681.80	477.01 ± 26.11
KF	ERT	82.07 ± 15.36	-58.00 ± 13.73	553.27 ± 270.53	3376.85 ± 541.01	475.81 ± 27.13
	TRT	88.02 ± 15.95	-62.06 ± 10.78	504.39 ± 209.97	3466.26 ± 472.75	484.05 ± 15.15

*ERT KE RTD_{0-50} significantly higher than TRT (p = 0.049)

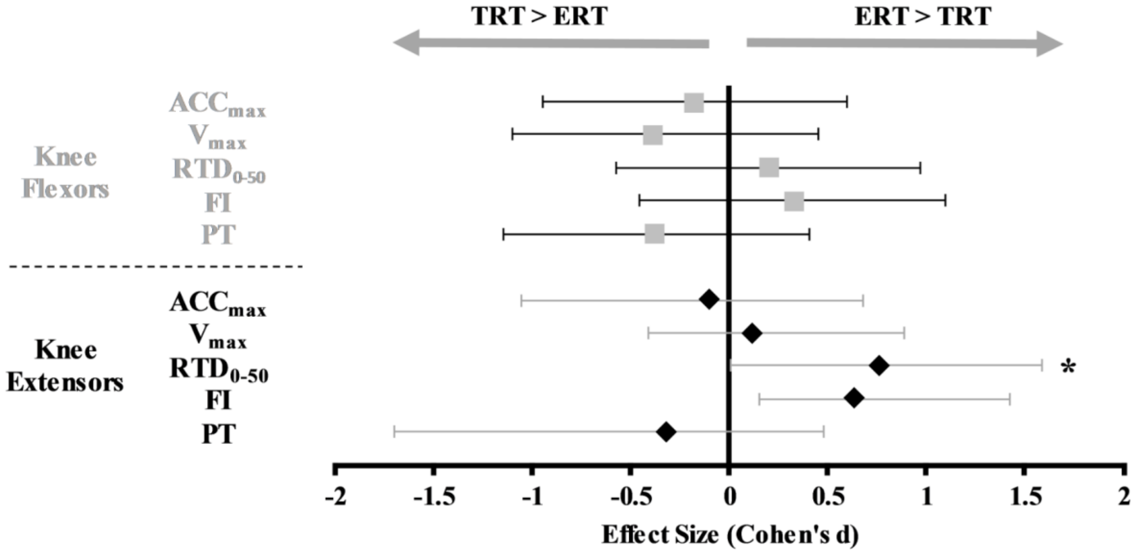

Figure 1. Cohen's d effect sizes and 95% confidence intervals for the knee flexors and extensors for each dependent variable measured between the traditional (TRT) and explosive (ERT) resistance-trained groups. Effect sizes were calculated such that a negative value signified that TRT had a greater mean, while a positive value showed that ERT had a greater mean. * = Significant difference between groups ($p \leq 0.05$).

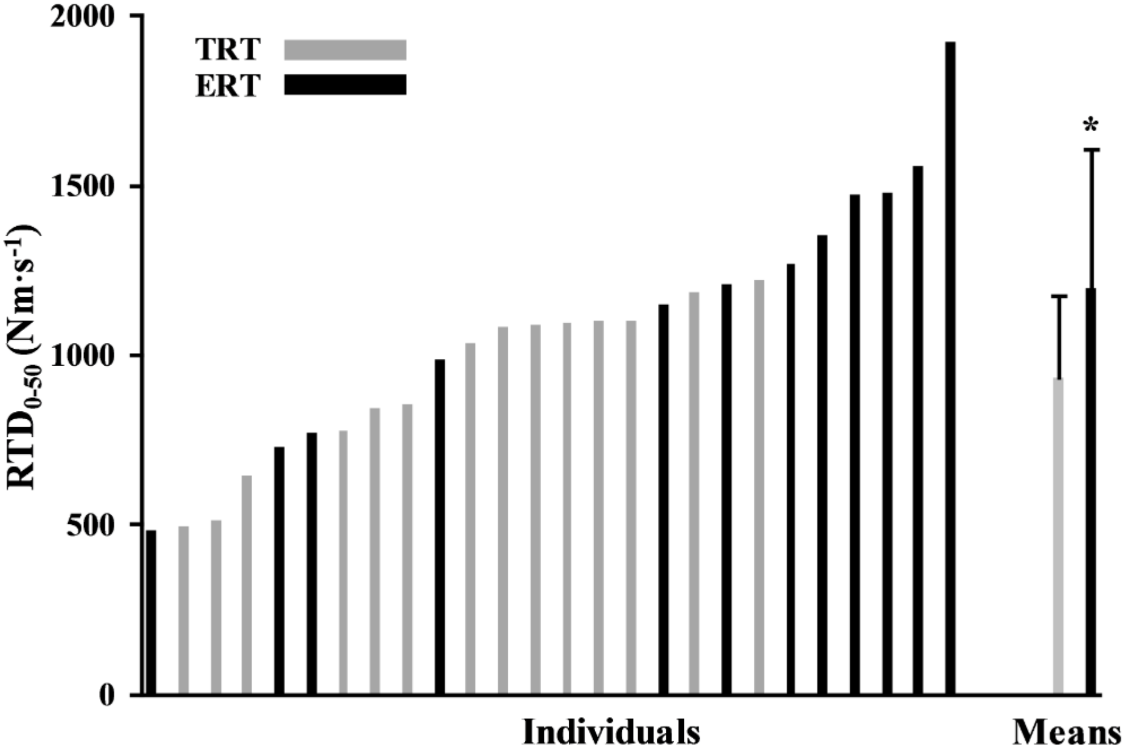

Figure 2. Early phase rate of torque development (RTD_{0-50}) scores for each individual assessed combined with the group means and standard deviations. * = Significant difference between groups (*p* = 0.049).

2.1.4. Discussion

The primary finding of the present study was the lack of differences between groups despite using variables that should be sensitive to training specificity. However, a significant difference was observed for knee extension RTD_{0-50}, in which the ERT group had greater early RTD values compared to the TRT group. Besides RTD_{0-50}, no differences were observed for any other variables between training statuses. The lack of differences observed in our study may have been attributed to the training status of the groups. Although there were obvious differences in workout regiments, on average each group had been resistance-training for 4-6 years, which could have led to an overlap in types of resistance-training exercises and consequently similar responses to training adaptations. Although our investigation was not a training study, a recent study by MacDonald et al. (2012) supports our findings. The authors compared the effects of six weeks of TRT, plyometric training, and complex training on measures of strength (back squat, dead lift, and calf raise) and observed no differences between groups. Additionally, the assessments utilized in this study may not have been specific enough to distinguish the differences between the two groups. The addition of more functional and/or invasive measures may reveal further dissimilarities between the groups training adaptations.

While early rate of force development (0-100 ms) is important for a variety of movements (e.g., sprinting, cutting, kicking, etc.), a potential reason for the present study's findings with knee extension $RTD_{0\text{-}50}$ could be related to the speed and quickness that ERT lifters perform movements compared to the TRT group. For example, rapid force production determines the magnitude of acceleration in the initial phase of a movement and ultimately affects the velocity of the movement (Aagaard et al. 2002; Kraemer and Newton 2000). Additionally, previous studies that have reported increases in early RTD involved exercises that were executed with maximal acceleration effort (i.e. RFD/RTD) (Behm and Sale 1993; Caserotti et al. 2008; Suetta et al. 2004; Van Cutsem et al. 1998; Young and Bilby 1993). Specifically, Young and Bilby (1993) demonstrated that performing resistance-training exercises with maximal acceleration efforts increased RFD more than when exercises were performed in a slow manner, despite similar loads lifted by the two training groups. As previously mentioned, the ERT group involves movements such as the snatch, hang clean, and push jerk which may contribute directly to explosive performance or strength (Caserotti et al., 2008) since these exercises involve attaining maximum or near maximum rate of force development to accomplish (Stone and O'Bryant 1987). Collectively, this emphasizes the importance of rapid force characteristics in relation to ERT.

Rate of force *or* torque development is a variable that has been previously assessed for TRT groups with inconsistent results. For example, Aagaard et al. (2002) utilized a heavy-resistance strength training intervention over 14-weeks and reported a significant 15-20% increase in early phase RTD (0-30, 0-50, 0-100 ms). Additionally, Thompson et al. (2015) revealed increases for the KE and KF for early and late phase RTD (0-50 & 0-200 ms) following 10-weeks of barbell deadlift training. In contrast, Andersen et al. (2010) implemented training program over 14-weeks and found that early phase RFD remained unchanged even though a significant increase in maximal strength was observed. In contrast, Marshall et al. (2011) reported a decrease for early phase RFD (0-30 & 0-50 ms) and RFD_{peak} in the KE following squat training. While TRT and early RTD has shown dissimilar responses post intervention, studies assessing RFD/RTD following ERT protocols appear to show a reliable increase (Gruber et al. 2007; Oliveira et al. 2013a; Oliveira et al. 2013b; Young and Bilby 1993). For example, Gruber et al. (2007) reported a 48% increase in RFD_{peak} following just 4-weeks of explosive resistance-training despite the MVC remaining unchanged. Also, Young and Bilby (1993) revealed a 68.7% increase in RFD_{peak} in the ERT (fast) group compared to just 23.5% in the TRT (slow) group following 7-weeks of squat training. While the present study assessed two different training groups (ERT and TRT), the existing findings suggest that baseline RTD_{0-50} of the KE was greater for the ERT compared to TRT groups. These findings may indicate that early phase RTD may be a more sensitive measure when distinguishing between two different resistance-trained groups and highlights the importance of rapid torque characteristics.

As aforementioned, this investigation revealed a significant difference for knee extension $\mathrm{RTD}_{0\text{-}50,}$ in which the ERT group had greater early RTD values compared to the TRT group. While it is plausible that this finding could be attributed to one's training background (explosive based contractions vs. a traditional controlled movement pattern), previous literature suggests that cross-bridge cycling rates, muscle fiber type, and calcium kinetics (Aagaard et al., 2002; Andersen, Andersen, Zebis, & Aagaard, 2010; Bottinelli, Canepari, Pellegrino, & Reggiani, 1996; Brody, 1976; Larsson & Moss, 1993) are directly related with early RTD. Therefore, the present findings could be directly related to these aforementioned characteristics. Additionally, knowing that TRT normally incorporates higher intensities at lower-speeds (Channell and Barfield 2008), whereas ERT performs movements at maximum or near maximum rates of force development (Stone and O'Bryant 1987), the baseline early RTD results suggest that ERT exercise prescriptions may provide significant differences in early RTD performance. Nevertheless, another unique finding from the present study was the lack of difference post fatigue between the two training groups, thus, while there was a significant difference between groups at baseline, similar fatigue related responses occurred immediately post exercise. As previously stated, this may be due to the training status of the groups. Specifically, resistance training causes a transition in myosin heavy chain (MHC) isoforms from MHCIIb to MHCIIa in as early as 4-12 weeks (Kraemer et al. 1995; Rapp and Weicker 1982; Staron et al. 1994). This transition of MHC isoforms corresponds to a shift from type IIB to type IIA fibers and facilitates fiber hypertrophy, which is associated with strength gains and increased oxidative capacity to the muscle, thus improving fatigue resistance of the trained muscles (Abernethy et al. 1994; Kraemer et al. 1996). In addition, we had expected that any adaptation that improves RTD would be accompanied by higher ACC and V_{max}. Surprisingly, our investigation did not reveal these variables to be greater as well. While the present study did not assess any recovery time besides immediately post-exercise, future studies may wish to incorporate a variety of training backgrounds (TRT, ERT, sedentary, endurance trained, etc.) assessment of muscle fiber type, EMG, as well as track an acute post exercise recovery period to see if there are similar or dissimilar recovery patterns between training status, further, incorporating assessments of rapid and maximal strength could add to the literature.

Although the present investigation used an isokinetic dynamometer to assess PT, RTD, V_{max}, and ACC_{max}, we acknowledge that not everyone has the ability to utilize this mode assessment. Future studies should consider comparing these performance measures from different, more practical dynamic exercises. In addition, the present study included only young resistance-trained individuals, thus, the measures may greatly differ compared to older populations that utilize the same training techniques. Lastly, it should be noted that our only significant difference between groups showed a *p*-value of 0.049, if we were to use a bonferroni correction due to the multiple comparisons this would change the alpha level required to 0.005.

2.1.5. Conclusion

This study was designed to determine if maximal and rapid force characteristics as well as fatigue responses of the knee extensors and flexors could discriminate between

TRT and ERT men. The evidence from the present study seems to support the idea that resistance-trained individuals may react similarly when put through a fatiguing bout of dynamic isokinetic exercise. However, it has been shown that the adaptations to training may be specific to the modality of the training. Therefore, it is possible that training specificity of the two groups (i.e., TRT and ERT) led to adaptations that may not completely transfer to isokinetic and isometric performance assessments since they are different modalities. In addition, the present study indicated a significant difference for the extensors, where RTD_{0-50} was higher for the ERT group compared to the TRT group. However, the greater RTD_{0-50} in ERT men was not accompanied by a significantly greater acceleration or maximal velocity. These findings demonstrate that measures of rapid force development may be more sensitive to training-specific adaptations than kinematic variables such as peak acceleration and velocity.

2.2. **Mackey, C.S.**, Thiele, R.M., Schnaiter-Brasche, J.A., Smith, D.B., Conchola, E.C. (2018). Acute recovery responses of maximal velocity and angular acceleration of the knee extensors following back squat exercise. *Isokinetics and Exercise Science*. 26(4), 281-290.

2.2.1. Introduction

A majority of fatigue-related research utilizes maximal and rapid strength characteristics while examining static muscle performance (Hakkinen, 1993; Thompson et al., 2013). Angular acceleration (ACC), which is defined as the ability to generate velocity rapidly (Thompson et al., 2014), and maximum unloaded velocity (Vmax) may be better suited for assessing variations in dynamic muscle function (Thompson et al., 2014). Previous research that investigated muscle function utilized muscle strength- and/or power-related measures to identify deficits in performance (Hakkinen, 1993; Conchola et al., 2015). Specifically, Häkkinen (1993) observed a decrease in isometric force of the knee extensors following a fatiguing squat protocol (20 × 1 × one-repetition maximum; 1-RM) in both males (24.1%) and females (20.5%). Similarly, Conchola et al. (2015) observed acute deficits in maximal and rapid strength capacities of the knee extensors following two separate free-weight back squat protocols (5 × 8 at 80% 1-RM and 5 × 16 at 40% 1-RM). Furthermore, Marshall et al. (2012) demonstrated similar acute deficits in maximal force following squat protocols (5 × 4 at 80% 1-RM) with differing inter-set rest intervals. While decreases in maximal strength have been observed post-exercise, assessing differences between sex (males and females) as well as other modes of measurement (dynamic, ACC and Vmax) may reveal another important aspect regarding functional deficits in performance. For example, Häkkinen (1993), and Linnamo et al. (1997) observed lower levels of overall fatigue (maximum strength) for the leg extensors for females compared to males. As the aforementioned investigations assessed acute recovery responses post-exercise, these studies only assessed maximal and rapid force, thus, to the author's knowledge, no previous research assessed gender differences following exercise protocols for ACC and Vmax. Additionally, no previous studies assessed recovery patterns from ACC and Vmax by gender. Examining and comparing these variables by gender may permit better understanding of physiological characteristics as well as practical responses from exercise based movements. Although rate of torque development (RTD) is a functionally significant indicator of rapid and forceful muscle actions, it may be limited in its practical application due to its conventional assessment during an isometric contraction in which muscle length and joint angle remains unchanged. While previous research generally assessed fatigue recovery patterns related to isometric force production, to the authors knowledge, only one study has assessed the impact of exercise on ACC (Nguyen et al., 2009). Nguyen et al. (2009), reported ACC deficits of ~11-12% immediately, ~8-9% at 24 hours, and ~10% at 48 hours after performing an eccentric muscle damaging protocol for the elbow flexors (6 × 10 at $30°\cdot s^{-1}$). Although force production is essential for athletic performance (Thompson et al., 2013; Aagaard et al., 2002; Marshall et al., 2011), it may not provide the most appropriate indicator of deficits in acceleration and velocity (Samozino et al., 2012; Samozino et al., 2008; Samozino et al., 2014) following exercise. Specifically, previous authors examined force-velocity (F-v) profiles for identifying the capacity of ballistic performance - ability to accelerate body mass as much as possible in the shortest time possible (Samozino et al., 2008) - for improvement through tailored training programs. The importance of examining a practical bout of exercise utilizing varying forms of resistance exercise protocols may provide novel information regarding the acute

(0-30 min) time-course effects of ACC and Vmax. Subsequently, the use of different free-weight back squat protocols with matched training volumes may elicit different responses on maximal and rapid velocity. Additionally, previous literature (although assessing strength) have seen significant differences between sex (males vs. females) in regard to maximal and rapid strength characteristics after performing matched exercise protocols (Hakkinen, 1993; Linnamo et al., 1997). Previous literature suggests that these findings could be related to muscle perfusion, differences in cross-sectional area, metabolic processes and ATP utilization (Hunter, 2014; Esbojornsson-Liljedahl et al., 2002). While decreases in performance may occur post-fatigue, there has been considerable evidence that fatigue is not caused by a single factor, but that the mechanisms underlying the force reduction are task specific (Enoka and Stuart, 1992; Gandevia, 2001). Furthermore, it is important to note that muscle power has been shown to be negatively affected more than maximal force following a dynamic fatigue protocol (James et al., 1995) and this reduction in force-producing capacity may lead to deficits in subsequent muscular performance, thus hindering physical ability post-exercise. Consequently, due to the explosive nature of a power-endurance (PE) exercise protocol, it follows that ACC and Vmax may be impacted to a greater amount than from a controlled-hypertrophic (CH) exercise protocol. Therefore, the purpose of the present study is to examine the effects of a power-endurance (PE) versus a controlled hypertrophic (CH) free-weight back squat exercise on the acute post-exercise recovery responses of maximal velocity and acceleration characteristics to the knee extensors. We hypothesized that the women would be more fatigue resistant compared to the men following both exercise protocols and that the PE protocol would elicit a greater amount of fatigue for ACC and Vmax compared to the CH protocol.

2.2.2. Methods

Experimental Subjects

Fourteen resistance-trained men (mean ± SD: age = 22.07 ± 2.6 years; height = 175.02 ± 8.80 cm; mass = 85.21 ± 8.4 kg; squat 1-RM = 144.16 ± 20.98 kg; squat 1-RM to mass ratio = 1.71 ± 0.30) and sixteen women (mean ± SD: age = 21.75 ± 1.0 years; height = 163.84 ± 8.23 cm; mass = 67.56 ± 8.98 kg; squat 1-RM = 92.61 ± 19.94 kg; squat 1-RM to mass ratio = 1.37 ± 0.33) volunteered to participate in this investigation. All participants were engaged in a structured weight training program that involved the lower body (including the free-weight back squat exercise) for a minimum of at least 6 months prior to the study. None of the participants reported taking any ergogenic supplements (i.e. caffeine or creatine) prior to the study, nor reported any musculoskeletal injuries of the lower extremities, within one year prior to testing. This study was approved by the University Institutional Review Board for human subject's research, and prior to any testing each participant voluntarily completed an informed consent document and health history questionnaire.

Procedures

This study used a randomized, within-subjects design to investigate the acute effects of two different fatigue-inducing protocols using the free-weight back squat exercise on angular acceleration (ACC) at $240°\cdot s^{-1}$ (ACC240), $500°\cdot s^{-1}$ (ACC500), and maximum unloaded velocity (Vmax). Participants performed maximum voluntary contractions (MVCs) of the knee extensors before (Pre) and 0 (Post0), 7 (Post7), 15 (Post15) and 30min (Post30) following a free-weight back squat workout involving either a PE (5×16 at 40% 1-RM) or a CH (5×8 at 80% 1-RM) loading protocol.

Back Squat 1-RM and Exercise Protocol

The back squat 1-RM and exercise protocols were performed in a multi-purpose adjustable Commercial Power Rack (RockSolid Fitness, Rutland, VT, USA) with a standard Olympic barbell (20.45 kg). With feet positioned shoulder width apart, participants used a high bar placement and squatted starting from an upright position and descending until a ~90° angle at the knees was achieved (Pincivero et al., 2000). An elastic band was set to provide the participants with kinesthetic feedback of when 90° was attained (Conchola et al., 2015). Each back squat 1-RM assessment was performed at a cadence of 60 $b \cdot min^{-1}$ (using a digital metronome), resulting in a tempo of 2 seconds for both the eccentric and concentric contraction phases, ensuring a consistent rhythm throughout each repetition (Hattin et al.,1989; Thiele et al., 2014). The back squat 1-RM testing began with a warm-up of 10 repetitions at 50% of the estimated maximal load. Following a rest period of 3 min, the back squat 1-RM was determined by selecting an initial load (~90% of their 1-RM), and subsequently applying incremental (2.27-9.09 kg) loads (Brown, 2007) until the participant could not complete a repetition using proper technique to depth or could no longer maintain the cadence (60 $b \cdot min^{-1}$) of the metronome. Additional trials were performed until the 1-RM was determined within 2.27 kg and the 1-RM was achieved in ≤ 5 trials. The highest successfully completed 1-RM was used in determining the load for the subsequent squat exercise protocols. During all testing, parallel safety bars were set 2-4 inches below the participant's 90° squat depth and a two-person spot was provided for all trials (Conchola et al., 2015, Marshall et al., 2012).

Participants were randomly assigned to either the PE or CH squat protocol on separate occasions (4-7 days following 1-RM testing and 7 days separated the experimental protocols). Each testing session began with a 5-minute warm-up on a cycle ergometer (Monark Exercise 828E, Vansbro, Sweden) at a self-selected low-intensity followed by a set of 10 repetitions at 50% of participant's 1-RM followed by either the PE or CH exercise protocols. The PE protocol consisted of 5 sets of 16 repetitions at an intensity of 40% of the participant's 1-RM and the CH protocol consisted of 5 sets of 8 repetitions at 80% of the participant's 1-RM. These loading schemes were selected to provide an equal total-volume between both protocols, while allowing for characteristics of each protocol to be exhibited (light load-explosive velocity vs. heavier load-slow velocity) (Conchola et al., 2015). During both protocols, 2 min of rest were allotted between each set, and a cadence of 60 $b \cdot min^{-1}$ was used for the repetitions during the fatigue protocols. Additionally, the same loading tempo as the 1-RM assessment (i.e., 2 second eccentric; 2 second concentric) was utilized for the CH protocol, however, for the PE protocol, participants were instructed to perform the concentric portion of each repetition "as rapidly and explosively as possible" while keeping their feet flat on the floor (Conchola et al., 2015). Although participants were instructed to perform ballistic concentric contractions during the PE protocol, the present study did not include assessments of bar displacement (i.e., Power and Velocity) during each repetition.

Maximal Voluntary Contractions

MVCs were performed with the right leg using a calibrated Biodex System 4 isokinetic dynamometer (Biodex Medical Systems, Inc. Shirley, NY, USA). Participants were seated with straps placed over the trunk, pelvis, and thigh and the input axis of the dynamometer aligned with the lateral condyle of the knee. Prior to testing, participants performed a 5-min warm-up on a cycle ergometer (Monark Exercise 828E, Vansbro, Sweden) at a self-selected low-intensity workload, followed by three submaximal isokinetic knee extensor muscle actions ($60°\cdot s^{-1}$) at 75% of their perceived maximal effort. Following the warm-up, participants performed three MVCs each at $240°\cdot s^{-1}$ and $500°\cdot s^{-1}$ (Vmax). Vmax was used to assess the maximum shortening capacity of the muscle-limb unit (Van Roie et al., 2013). The order of testing was randomized and one minute of recovery was provided between each contraction. For all MVCs, participants were instructed to "kick up" as "hard and fast as possible." (Weir et al., 1998). The range of motion was set to move from 90° to 10° of leg extension (0 = horizontal plane) (Weir et al., 1998). Immediately following all sets and repetitions of the exercise protocol, participants randomly performed three MVCs at $240°\cdot s^{-1}$ and at $500°\cdot s^{-1}$ (Vmax) for each post-time phase (i.e., Post0, Post7, Post15, and Post30 min).

Estimated Quadriceps Muscle Cross-Sectional Area

Estimated quadriceps muscle cross-sectional area (eQCSA) of the right thigh was determined using thigh circumference to the nearest 0.1 cm and skinfold measurements to the nearest 0.5 mm. Similar to Housh et al. (1995), anthropometric measures were all taken on the right side of the body, with participants standing in a weight-bearing, erect position. A mid-thigh circumference was obtained using a tension-gauged measuring tape (Gullick II; Country Technologies, INC., Gays Mills, Wisconsin) and skinfolds were measured using a Lange caliper (Beta Technology, Santa Cruz, California). For mid-thigh circumference measurements, participants were asked to equally distribute their weight with feet shoulder width apart while positioning their right leg at roughly 90 degrees on an 18” box. Skinfold measurements were obtained from the anterior thigh, mid-way between the inguinal crease and proximal border of the patella (Housh et al., 1995). Estimated quadriceps muscle CSA (cm^2) was calculated using the equation of Housh et al. (1995):

$$\text{Quadriceps CSA} = (2.52 \times \text{mid-thigh circumference in cm}) - (1.25 \times \text{anterior thigh skinfold in mm}) - 45.13$$

Signal Processing

The velocity ($deg \cdot s^{-1}$) signal was sampled at 2 KHz with a Biopac data acquisition system (MP 150WSW, Biopac Systems Inc.; Santa Barbara, CA) stored on a personal computer (Dell Inspiron, Dell Inc., Round Rock, TX) and processed offline with custom written software (Labview 8.5, National Instruments, Austin, TX). The scaled velocity signal was filtered using a fourth-order, zero-phase shift, low pass Butterworth filter with a 10-Hz cutoff frequency. Vmax was calculated as the highest velocity attained during the unloaded MVC. ACC ($deg \cdot s^{-2}$) was determined as the linear slope of the velocity-time curve (Δvelocity/Δtime) for the 240 $deg \cdot s^{-1}$ (ACC240) (Figure 3) and maximal unloaded velocity (ACC500) contractions. ACC was calculated from the onset of velocity to the point where the signal reached 2 $deg \cdot s^{-1}$ below the target velocity level (238 $deg \cdot s^{-1}$) and at 2 $deg \cdot s^{-1}$ below Vmax for ACC240 and ACC500, respectively. These procedures acquired the linear portion of the rate of rise in velocity, while excluding the deceleration or "rounding off" of the signal observed at the edge of the velocity plateau. The onset of velocity was determined as the point when the velocity signal reached a threshold of 2 deg·s^{-1} above baseline. The MVC with the highest ACC or Vmax was used for all analyses. In addition, the range of motion (ROM, deg) for both the acceleration and deceleration phases of the contraction were calculated (Brown et al., 2005).

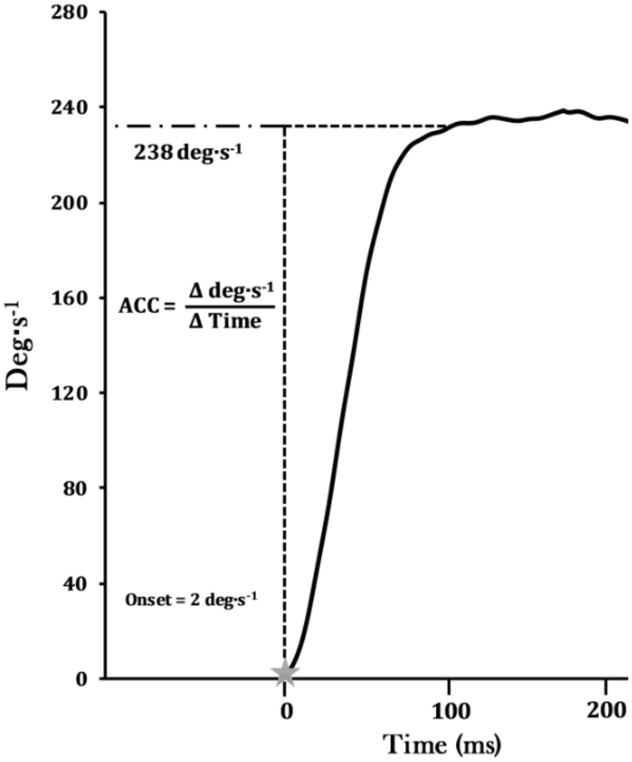

Figure 3. Angular acceleration (ACC; deg·s^{-2}) was determined as the linear slope of the velocity-time curve (Δvelocity/Δtime) for the 240 deg·s^{-1} (ACC240) (as shown) and maximal unloaded velocity (ACC500) contractions. ACC was calculated from the onset of velocity to the point where the signal reached 2 deg·s^{-1} below the target velocity level, which was at 238 deg·s^{-1} and at 2 deg·s^{-1} below Vmax for ACC240 and ACC500.

Statistical Analyses

Three separate, 3-way mixed factorial ANOVAs [Sex (males vs. females) × intensity (CH vs. PE) × time (Pre vs. Post0 vs. Post7 vs. Post15 vs. Post30)] were used to analyze ACC240, ACC500 and Vmax. When appropriate, follow up analyses included one-way repeated measures ANOVAs and t-tests with bonferonni-corrections on either the simple main effects or main effects collapsed across the opposing variable. In the case of the violation of sphericity Greenhouse-Geisser results were reported. Partial eta squared (ηp2) values were reported to estimate ANOVA effect sizes. Statistical analyses were performed using PASW software version 20.0 (SPSS Inc, Chicago, IL, USA), and an alpha level of $p \leq 0.05$ was used to determine statistical significance.

2.2.3. Results

Means and SD values for velocity data are presented in Table 2. Absolute ACC240, revealed no sex × intensity × time ($F_{2.79,\ 28} = 1.56$; $p = 0.207$), nor sex × time ($F_{2.31,\ 28} = 1.06$; $p = 0.361$), sex × intensity ($F_{1,\ 28} = 0.62$; $p = 0.436$), or intensity × time ($F_{2.79,\ 78.15} = 2.42$; $p = 0.077$) interactions. There was however a significant main effect for time ($F_{2.31,\ 64.79} = 17.10$; $p \leq 0.001$, $\eta_p^2 = 0.379$) in which ACC240 was greater at Pre than at Post0 ($p \leq 0.001$), Post15 ($p = 0.023$) and Post 30 ($p = 0.015$). In addition, Post0 was significant from all following time points ($p \leq 0.001$-0.015). However, no significant differences were observed between Post7 and all other time points (i.e. Post15 and Post30; $p > 0.05$). Absolute ACC500 revealed no sex × intensity × time ($F_{2.65,\ 28} = 1.64$; $p = 0.192$), nor sex × time ($F_{2.09,\ 28} = 2.19$; $p = 0.119$), intensity × sex ($F_{1,\ 28} = 2.28$; $p = 0.142$) or intensity × time ($F_{2.65,\ 74.22} = 1.62$; $p = 0.198$) interactions. There was however a significant main effect for time ($F_{2.09,\ 58.64} = 33.64$; $p \leq 0.001$, $\eta_p^2 = 0.546$) in which ACC500 was greater at Pre than all post-recovery time phases (Post0-Post30; $p \leq$

0.001). Additionally, ACC500 remained significantly reduced at Post0 in comparison to all following time phases (Post7-Post30; $p \leq 0.001$). However, while still reduced from Pre, there were no significant differences between Post7-Post30 ($p > 0.05$).

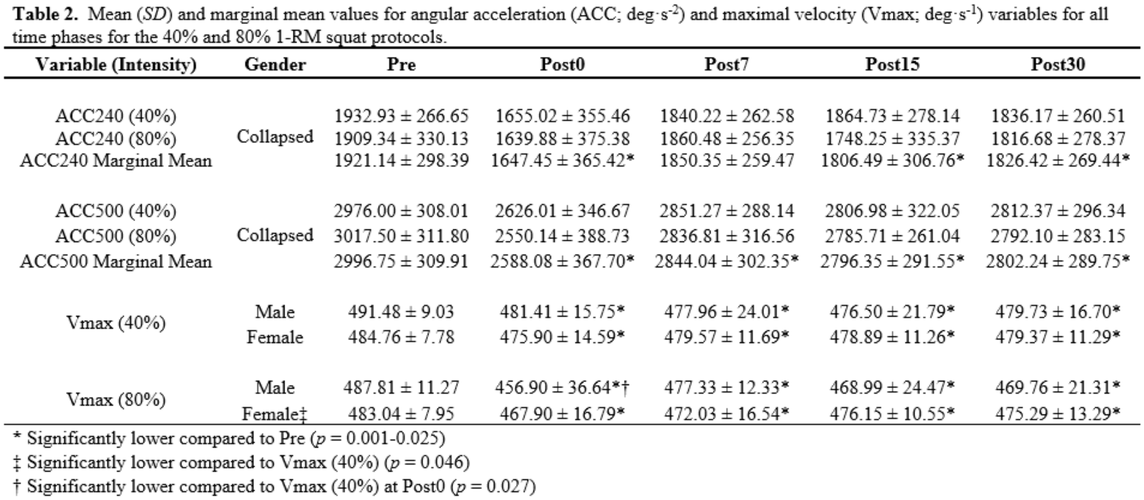

Table 2. Mean (*SD*) and marginal mean values for angular acceleration (ACC; deg·s^{-2}) and maximal velocity (Vmax; deg·s^{-1}) variables for all time phases for the 40% and 80% 1-RM squat protocols.

Variable (Intensity)	Gender	Pre	Post0	Post7	Post15	Post30
ACC240 (40%)	Collapsed	1932.93 ± 266.65	1655.02 ± 355.46	1840.22 ± 262.58	1864.73 ± 278.14	1836.17 ± 260.51
ACC240 (80%)		1909.34 ± 330.13	1639.88 ± 375.38	1860.48 ± 256.35	1748.25 ± 335.37	1816.68 ± 278.37
ACC240 Marginal Mean		1921.14 ± 298.39	1647.45 ± 365.42*	1850.35 ± 259.47	1806.49 ± 306.76*	1826.42 ± 269.44*
ACC500 (40%)	Collapsed	2976.00 ± 308.01	2626.01 ± 346.67	2851.27 ± 288.14	2806.98 ± 322.05	2812.37 ± 296.34
ACC500 (80%)		3017.50 ± 311.80	2550.14 ± 388.73	2836.81 ± 316.56	2785.71 ± 261.04	2792.10 ± 283.15
ACC500 Marginal Mean		2996.75 ± 309.91	2588.08 ± 367.70*	2844.04 ± 302.35*	2796.35 ± 291.55*	2802.24 ± 289.75*
Vmax (40%)	Male	491.48 ± 9.03	481.41 ± 15.75*	477.96 ± 24.01*	476.50 ± 21.79*	479.73 ± 16.70*
	Female	484.76 ± 7.78	475.90 ± 14.59*	479.57 ± 11.69*	478.89 ± 11.26*	479.37 ± 11.29*
Vmax (80%)	Male	487.81 ± 11.27	456.90 ± 36.64*†	477.33 ± 12.33*	468.99 ± 24.47*	469.76 ± 21.31*
	Female‡	483.04 ± 7.95	467.90 ± 16.79*	472.03 ± 16.54*	476.15 ± 10.55*	475.29 ± 13.29*

* Significantly lower compared to Pre ($p = 0.001$-0.025)
‡ Significantly lower compared to Vmax (40%) ($p = 0.046$)
† Significantly lower compared to Vmax (40%) at Post0 ($p = 0.027$)

For Vmax, a significant sex × intensity × time interaction ($F_{2.71, 28} = 3.005$; $p = 0.040$) was observed. Four separate two-way ANOVAs were utilized in decomposing the model (time × intensity for males and females only, sex × time for the PE intensity only, and sex × time for the CH intensity only). No time × intensity interaction was observed for the females ($F_{4, 15} = 2.41$; $p > 0.05$). There was a main effect for intensity ($F_{1, 15} = 4.72$; $p = 0.046$, $\eta_p^2 = 0.24$) in females, in which pairwise comparisons revealed that PE was greater than CH ($p = 0.046$). In addition, a main effect for time ($F_{4, 60} = 12.67$; $p = 0.001$, $\eta_p^2 = 0.458$), was observed, in which Vmax was greater at Pre than all post-recovery time phases (Post0-Post30) ($p = 0.001$-0.005). A significant time × intensity interaction was observed ($F_{2.45, 14} = 3.77$; $p = 0.027$) for males, in which all post-recovery time phases (Post0-Post30) were lower for both the PE ($p = 0.002$-0.025) and CH ($p = 0.002$-0.012) protocols compared to Pre. However, when comparing intensities at each time phase, the CH protocol was significantly lower ($p = 0.019$) than the PE protocol at Post0. No inter-intensity differences were observed at Pre, Post7, Post15 and Post30 ($p = 0.113$-0.896).

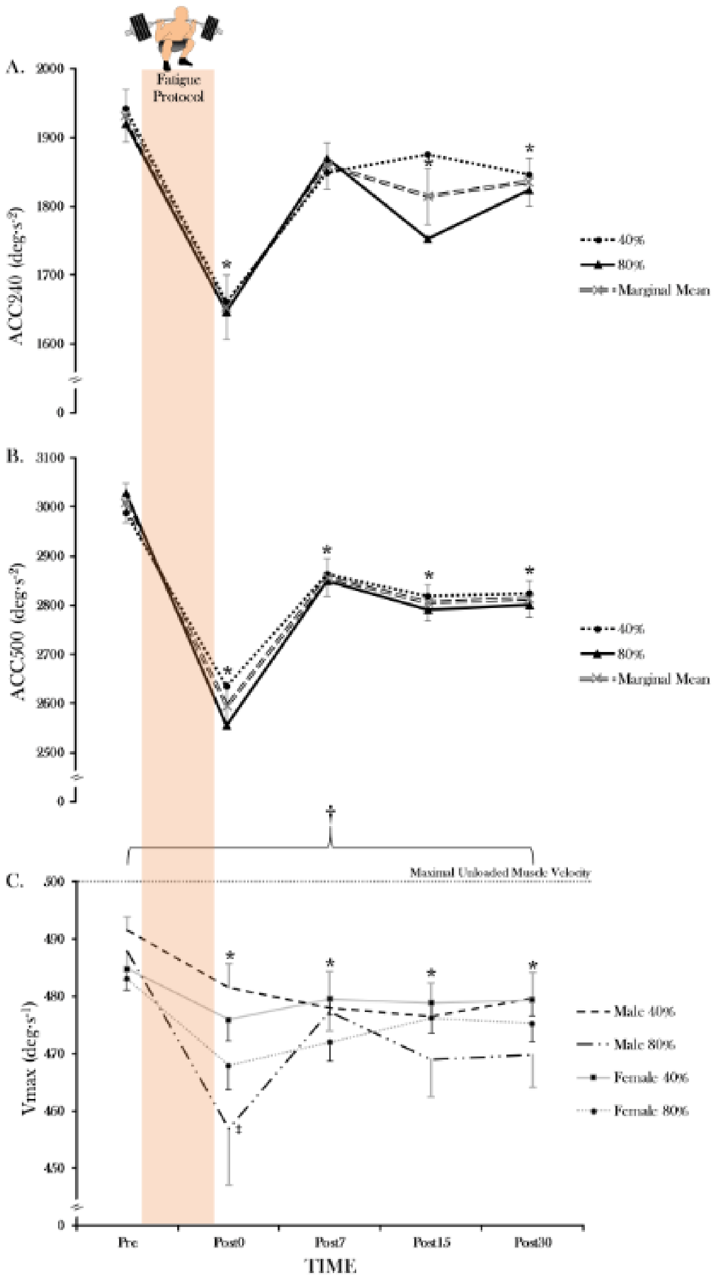

Figure 4. Mean (SEM) values for (A) angular acceleration (ACC; deg·s^{-2}) 240, (B) ACC500, and (C) maximal velocity (Vmax; deg·s^{-1}) variables for all time phases for the 40% and 80% 1-RM squat protocols. *Significantly lower compared to Pre ($p = 0.002$-

0.025). †Significant sex × intensity × time interaction ($p = 0.040$). ‡Significantly lower compared to Vmax (40%) at Post0 ($p = 0.027$) for males.

2.2.4. Discussion

The primary findings of the present investigation revealed no intensity or sex differences for ACC240 or 500 when performing either the PE or CH free-weight back squat protocol. While ACC240 and 500 remained negatively affected post-exercise (Figure 2a;2b), a significant sex-specific intensity difference for Vmax was present in which the men exhibited a significant difference at Post0 for the CH protocol compared to the PE protocol (Table 2). All Vmax values post-exercise were significantly decreased throughout recovery (Post0-Post30) (Figure 4c).

The present findings observed a significant decrease in ACC following the completion of the squat protocols. Specifically, ACC240 was lower at Post0, Post15, and Post30 compared to Pre and ACC500 was lower at all post-recovery time points (Post0-Post30) compared to Pre (Figure 4a;4b). The variable ACC has been defined as velocity divided by the time to reach that velocity and may result from increases in torque production (Marshall et al., 2012; Brown et al., 2005). Being that force equals the product of mass and acceleration, increasing ACC while mass remains constant positively affects force production. Therefore, the ability to reach top speed quickly (ACC) may be more advantageous to human performance than simply attaining a greater top speed (Marshall et al., 2012; Brown et al., 2005; Murray et al., 2007). Previously, studies investigated the effects of age (Thompson et al., 2014; Yamauchi et al., 2010) and training on ACC (Murray et al., 2007; Brown and Whitehurst, 2003). However, there is a paucity of literature on the effects of fatigue on ACC for the knee extensors. While no previous research assessed acute recovery of ACC (≤30 minutes post workout) for the knee extensors, Nguyen et al. (2009) observed a decrease in ACC240 up to 72 hours post-fatigue for the elbow flexors. Interestingly, Nguyen et al. (2009) and the present study assessed different muscle groups and revealed similar deficits (~11-12% and ~14%) for ACC240 immediately following the exercise protocols. Although direct comparisons between the present study and Nguyen et al. (2009) are impractical due to the method of fatigue (compound movements vs. eccentric muscle actions), and different muscle groups (knee extensors vs. elbow flexors), it is important to note the negative exercise-induced effect on ACC performance (Nguyen et al., 2009; Senefeld et al., 2013). For the present study, ACC240 and 500 were negatively affected post-exercise. Although no significant difference was observed between Pre and Post7 ($p = 0.186$) for ACC240, there was still a ~4% reduction at Post7 (mean ± SD; 1850.35 ± 259.47) compared to Pre (1921.14 ± 298.39; Table 2; Figure 4). These time-course effects for ACC240 are similar to the ACC500 recovery responses (~4-5% performance reduction) at Post7, in which a substantial amount of performance restoration (~9-10%) was observed and maintained throughout recovery (Post7-Post30). Thus, no attributable physiological mechanism may explain the differential recovery patterns observed for ACC240 at Post 7. Ultimately, similar fatigue-related responses occurred with both genders. The present study's findings may be attributed to controlling for overall training volumes. Controlling for overall training volume may have prevented different levels of peripheral fatigue which could have occurred through alterations in calcium kinetics and cross-bridge cycling rates (Kent-Braun et al., 2012; Tesch et al., 1986). In addition to peripheral fatigue, stimulation of group III & IV chemoreceptor afferent neurons, which have inhibitory effects on the α-motoneurons innervating the fatigued muscle (Bigland-Ritchie et al., 1986), could have also negatively affected performance. Consequently, these fatigue-related alterations may explain why the rapid muscle contraction processes were negatively affected post-exercise. Nevertheless, while the present study saw similar fatigue and recovery related responses between genders, future studies may look at different dynamic exercises and recovery responses with more in-depth analysis of muscular contractions (EMG, MMG, muscle biopsy, co-activation, etc.).

While limb angular acceleration is an important indicator of movement capacities, the ability to generate maximum unloaded velocity may be an equally sensitive and important measurement to assess. Velocity is a principal contributor to muscle power (i.e., power = force × velocity) and may help identify the specific component of power most susceptible to acute fatigue. Additionally, Vmax has been used to assess potential differences in age (Thompson et al., 2014, Larsson et al., 1979), gender (Yamauchi et al., 2010), and acute muscle fatigue (Buttelli et al., 1996). An interesting finding from the present study was the significant sex-specific difference between exercise protocols for our male subjects. The CH protocol elicited greater amounts of fatigue at Post0 compared to the PE protocol (6.34 vs. 2.05%). The immediate fatigue response sustained from the CH compared to the PE protocol could be attributed to higher metabolic by-product accumulation (hydrogen ions), as a result of greater muscle mass in our male subjects, as evidenced by their significantly ($p = 0.011$) greater (78.06 ± 8.58 cm^2 vs 62.64 ± 15.47 cm^2) eQCSA. While cellular mechanisms are directly related to Vmax, muscle fiber type may play a significant factor. Specifically, fast-twitch (FT) muscle fibers have a substantially greater power capacity compared to slow twitch (5-10 vs. 3-4 times more powerful) (Kent-Braun et al., 2012). Since the knee extensor muscles are predominantly FT (56.3-70.5%) (Johnson et al., 1973), it is possible that the present findings could be credited to the greater utilization of FT muscle fibers with heavier intensities during the CH protocol (Fry, 2004). Aside from the intensity difference for males at Post0, all Vmax values were significantly decreased for both genders throughout recovery (Post0-Post30). These findings are similar to Butelli et al. (1996) who observed a significant deficit in maximal velocity (31%) immediately after performing a maximal cycling protocol. While the present study performed dissimilar fatiguing protocols (resistance exercise vs. cycling) and assessed recovery for an extended period of time (≤30 min), the overall decrease of Vmax was similar throughout all of recovery. Thus, with the current study implementing both a high-intensity, slow velocity and low-intensity, fast velocity exercise-intervention, increases with hydrogen ion production, and slowing of the sarcolemma and t-tubule conduction may have also occurred (Fitts, 2006; Zhou, 1996). While there was a significant sex and intensity difference, future recovery-based (≤30 min) research is needed for assessing maximum velocity of the knee extensors and flexors, following a variety of fatiguing tasks (static or dynamic) across different populations and activity levels.

2.2.5. Conclusions

Knowing that a variety of populations implement compound movements into their resistance training routines, the present findings suggest that ACC and Vmax may be negatively affected following moderate to heavy exercise. Thus, assessing ACC and Vmax following exercise may be a valuable measure in identifying the residual consequences of fatigue over a short-term recovery period. Given Vmax was significantly decreased for at least 30 minutes post-exercise, the present findings may suggest inclusion of this variable when building a performance profile (i.e., Force-velocity profile) and assessing fatigue related responses post-exercise (strength, power, and velocity). Although maximal and rapid velocity capabilities between genders responded similarly following fatiguing bouts of exercise, it is unclear as to whether ACC and Vmax are sensitive enough measures to reveal gender differences following this type of fatiguing protocol. Future studies may consider implementing different exercise protocols and more in-depth analyses of muscular contractions to distinguish potential sex- and recovery-related differences in ACC and Vmax. Furthermore, a recovery period of up to 30 min may yield impaired physiological and functional characteristics for individuals who perform tasks similar to the present study. Thus, clinicians, practitioners, and strength and conditioning professionals may use caution when designing lower-extremity exercises, as velocity characteristics may be diminished for an acute period of time (0-30 minutes) post-exercise. While the present investigation used an isokinetic dynamometer to assess ACC and Vmax, we acknowledge that not everyone has the ability to utilize this mode assessment. In addition, the present study included resistance-trained individuals, thus, the recovery responses may greatly differ compared to sedentary or older populations. Lastly, the present study controlled for overall total volume between the training protocols. While this may be common for recreational and lab based training, the present exercise protocols may not be applicable across all activity levels.

In summary, the present investigation observed similar fatigue and recovery-related responses between genders in their ability to generate velocity rapidly (ACC) following PE and CH squat protocols. Similarly, apart from the intensity difference for males at Post0, all Vmax values post-fatigue were significantly decreased throughout all of recovery (Post0-Post30). Given the importance of maximal and rapid velocity capacities in many sports and tasks of daily living (e.g., accelerating, cutting, stepping, etc.) (Thompson et al., 2013; Nguyen et al., 2009; Buttelli et al., 1996), the present findings reveal that a practical bout of lower body resistance exercise may reduce velocity capabilities for up to 30 minutes following a single exercise.

2.3. **Mackey, C.S.**, Thiele, R.M., Smith, D.B., Conchola, E.C. Effects of power-endurance and controlled heavy squat protocols on vertical jump performance in females. *International Journal of Exercise Science*, 2020. (In Review).

2.3.1. Introduction

Complex processes associated with brief bouts of muscular contractions (dynamic or otherwise) may lead to differences in subsequent performance responses. This may primarily depend upon the characteristics of muscle action/activation strategy or influences of task familiarity, resulting in enhanced muscular performance (postactivation potentiation), or deficits to any related performance characteristics (fatigue) (Tillin and Bishop, 2009). For example, previous lab-specific techniques (e.g., isokinetic dynamometry) have resulted in maximal and rapid force/strength deficits following dynamic exercise protocols (leg press, squat, leg extension) (Chiu et al., 2004; Conchola et al., 2015; Hakkinen, 1993; Linnamo et al., 1997; Witmer et al., 2010). Although decreases (18-48%) (Conchola et al., 2015; Witmer et al., 2010) in maximal strength post-exercise (measured upon completion of last set) have been reported, a greater emphasis on immediate (intraset, and within exercise bout) and acute recovery responses is needed for a variety of purposes (injury prevention, exercise program design, determining physiological responses).

Training programs are certainly intended to improve specific variables (strength, speed, agility, lean body mass) over the course of various training blocks (meso, macro, micro cycles), however, understanding the potentially less intuitive (intraset and acute) responses to a multi-set bout of resistance training may help guide deliberate alterations to the program. Interestingly, due to the nature of commonly utilized traditional resistance exercise protocols, many authors have commonly focused on the accumulation effect of exercise (i.e. acute recovery) on performance. For example, Conchola et al. (2015) observed decreased maximal and rapid strength (up to 30 minutes) after performing work matched free-weight squat protocols in resistance trained males. Although a dissimilar exercise was utilized, Linnamo, Hakkinen and Komi (1997) reported greater force deficits (23.7%) after a maximal [5 × 10 at 80% One-repetition maximum (1-RM)] leg extension exercise protocol compared to its explosive (5 × 10 at 40% 1-RM) counterpart (11% force deficit). However, recent authors have utilized innovative augmented volume loading schemes, through paired-set training (the use of agonist and antagonist exercises performed in an alternating manner) and reduced rest intervals, to maximize time-efficiency compared to traditional-set training (all sets of the same exercise are performed before the execution of all sets of the next exercise) (Paz et al., 2017). Since most sport-related activity requires consistent dynamic effort across repetitive bouts of explosive tasks, measuring intraset performance may provide a more comprehensive illustration of the sub-accumulation effect of exercise/activity. Additionally, the utilization of practical assessments may assist with distinguishing task- or training-specific adaptations as alterations to programs (e.g., intensity, volume, rest intervals, etc.) are inevitably implemented.

While the findings of the aforementioned authors have provided novel information, lab-specific techniques/assessments are often costly, difficult to replicate and/or are an unfamiliar task, and generally focus on a specific demographic (i.e., trained participants). Thus, functionally relevant assessments may allow for better interpretation of practical performance characteristics as well as an improved application for broader populations (sedentary, active, elderly). Specifically, the vertical jump [counter movement jump (CMJ), squat jump, drop jump] may serve as a simple, yet effective mode of assessing functional performance across a variety of individuals. Distinct baseline vertical jump characteristics [e.g. jump height (JH), peak velocity (PV), peak power (PP), etc.], have been used to differentiate athletic status/playing status, and create descriptive profiles (i.e. force-velocity; F-v) (Magrini et al., 2018), which may be affected following dynamic exercise (Byrne and Eston, 2002; Hester et al., 2014; Smilios et al., 2005). For example, Smilios et al. (2005) reported vertical jump height was decreased following maximal velocity squats and leg press (4 × 10 based upon 10-RM). In contrast, Saez de Villarreal, Gonzalez-Badillo and Izquierdo (2007) observed significant increases in vertical jump height following high intensity based squats (>80% 1-RM). Interestingly, Gilbert and Lees (2005) reported greater counter movement vertical jump height deficits following a maximal strength (5 × 1-RM load) compared to a maximal power (5 × load at which participants developed maximum power) squat protocol. Taken together, although different exercise loads and intensities were used, diverse findings are present when assessing vertical jump performance following lower-extremity exercise protocols. These differences may be attributed to varying research questions (fatigue versus potentiation), lower-body exercises (leg press, leg extensions, back-squat), training volume, and/or training intensity utilized for example.

Although the aforementioned studies assessed vertical jump performance following the completion of exercise (accumulating effects), interpreting immediate (intraset, and within-exercise bout) responses may be just as important for a variety of populations (sedentary, recreationally active, athletic, etc.). For example, Hester et al. (2014) examined the intraset effects of a high-volume power-oriented back squat protocol

(5 × 16 at 40% 1-RM, 2-minute rest interval) on PP of the squat movement (measured by a linear transducer secured to the barbell). Interestingly, PP was significantly reduced from the first repetition to the last repetition, however, no differences were observed in the highest PP repetition between sets. While novel, it is important to note that a 2-minute rest period may be sufficient for recovery of PP between sets following a high-repetition squat protocol. The inclusion of another protocol using a different intensity or load may have revealed differential responses for PP (or other performance measures) within- and/or between-sets. A study by Walker, Davis, Avela and Hakkinen (2012) assessed the within-exercise bout effects of a maximal strength (15 sets at 1-RM) versus hypertrophic (5 sets at 10-RM) resistance loadings on concentric load and maximal isometric force pre-, mid-, and up to 30 minutes post-loading. However, to ensure successful lifts, concentric load had to be significantly reduced at set 10 and 15 of the maximal strength protocol, while the load was maintained during the hypertrophic protocol. Both protocols significantly reduced maximal isometric force from pre- to mid-loadings, however, the deficit remained unchanged from mid- to post-loading for the maximal protocol but continued to decrease during the hypertrophic protocol. While exercise design (maximal vs. hypertrophic) can elicit specific performance responses, the addition of a within-exercise bout assessment and across the acute recovery phase (5, 10, 20 minutes post exercise) may help further elucidate within-exercise bout and acute (recovery) responses to exercise mode and design.

Limited research has examined vertical jump performance post-exercise, and to our knowledge, only one study has assessed other variables besides PP and JH after performing a squat protocol (Hester et al., 2017). While power is a convenient assessment to examine functional performance, and is commonly reported with jump studies (Hester et al., 2017; Lowery et al., 2012), examining the within-exercise bout and acute (recovery) responses for PV could be beneficial in providing an additional degree of specificity on the impact squat protocols have on vertical jump performance. A variety of athletic jumps have been used in research (squat jump, drop jump, CMJ), however the CMJ, which utilizes the stretch-shortening cycle by a downward countermovement from a standing position, provides a practical movement pattern used by a variety of populations, and has been utilized to measure dynamic muscle function (Byrne and Eston, 2002). For instance, Lowery et al. (Lowery et al., 2012) utilized a volume-matched squat protocol, and while only one set was performed (low intensity 1 × 5 at 56%, moderate intensity 1 × 4 at 70%, and high intensity 1 × 3 at 93% 1-RM), this study tracked CMJ performance (height and power) up to 12 minutes post-exercise. Their results revealed that while no changes in CMJ performance occurred in the low intensity bout, the moderate and high intensity bouts showed an increase in CMJ performance (~5% and ~7%, respectively) at 4 minutes post-exercise and returned to baseline by 8 minutes post-exercise. Thus, the ability to identify direct and acute responses post-exercise may be important in further determining the impact different loadings/intensities have on functional performance. Therefore, the purpose of this investigation was to examine the immediate (within exercise bout) and acute (recovery) performance responses after performing two different (controlled heavy vs. power-endurance) free-weight back squat exercise protocols on vertical jump performance in females.

2.3.2. Methods

Participants

A power analysis conducted with G*Power 3.1.9.4 (Universitat Kiel, Germany) determined that 7 participants were needed in the present study for a power of 0.80, with an effect size of 0.5 and an alpha level of 0.05. Fifteen resistance-trained women (mean ± SD: age = 21.8 ± 0.9 years; height = 164.6 ± 8.4 cm; mass = 68.5 ± 9.2 kg; 1-RM = 94.2 ± 20.8 kg; 1-RM to mass ratio = 1.4 ± 0.35) volunteered to participate in this investigation. All participants were engaged in a structured weight training program that involved the lower body (including the free-weight back squat exercise) for a minimum of at least 6 months prior to the study. None of the participants reported taking any ergogenic supplements (i.e. caffeine or creatine) prior to the study, nor reported any musculoskeletal injuries of the lower extremities, within 1 year prior to testing. This study was approved by the University Institutional Review Board for human subject's research, and prior to any testing each participant voluntarily completed an informed consent document and health history questionnaire. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (Navalta et al., 2019).

Protocol

This study used a randomized, repeated measures design to investigate the immediate performance responses (within exercise bout) and acute (recovery) effects of two different free-weight back squat exercise protocols on vertical jump performance: PP, mean power (MP), PV, mean velocity (MV), and JH. Participants visited the laboratory on three occasions separated by 4-7 days. The first visit consisted of familiarization to testing procedures, and a 1-RM of the free-weight back squat exercise was determined. On the second and third visit the participants were randomly assigned to either a power-endurance (PE; 5×16 at 40% 1-RM) or controlled heavy squat protocol (CHP; 5×8 at 80% 1-RM). Participants performed vertical jumps before (Pre), immediately after set one (S1), set two (S2), set three (S3), set four (S4), set five (S5/Post0), 5-minutes (Post5), 10-minutes (Post10), 15-minutes (Post15), and 20-minutes (Post20) following either the PE or CHP.

Back Squat 1-RM and Exercise Protocols: The back squat 1-RM and exercise protocols were performed in a multi-purpose adjustable Commercial Power Rack (RockSolid Fitness, Rutland, VT, USA) with a standard Olympic barbell (20.45 kg). With feet positioned shoulder width apart, participants used a high bar placement and squatted starting from an upright position and descending until a ~90° angle at the knees was achieved (Pincivero et al., 2000). An elastic band was set for each participant to provide them with kinesthetic feedback of when a 90° knee angle was achieved in order to promote consistent squat depth for each repetition (Conchola et al., 2015). Each back squat 1-RM assessment was performed at a cadence of 60 b·min-1 (using a digital metronome), resulting in a tempo of 2 seconds for both the eccentric and concentric contraction phases, ensuring a consistent duration of muscle tension throughout each repetition (Hattin et al., 1989; Thiele et al., 2014). The following back squat 1-RM procedures were described by Brown (2007). All participants achieved a 1-RM in ≤ 5 trials, with 3 minutes rest after each trial. Testing began with a warm-up of 10 repetitions at 50% of the estimated maximal load. The 1-RM was determined by selecting an initial load that the participant estimated would be approximately 90% of their 1-RM and subsequently applying incrementally small (2.27-9.09 kg) loads until the participant could not complete a repetition using proper technique through the full range of motion or could no longer maintain the cadence (60 b·min-1) of the metronome. Additional trials were performed until the 1-RM was determined within 2.27 kg and using these procedures.

The two different squat protocols were work-matched for an equal load volume to allow for potential protocol-specific characteristics to be demonstrated (power-endurance vs. controlled-hypertrophic). The exercise protocols have been previously described (Conchola et al., 2015; Hester et al., 2014; Thiele et al., 2014). In short, participants were randomly assigned to either the PE or CHP squat protocol on separate occasions (4-7 days following 1-RM testing, with 7 days separating the experimental protocols). Each testing session was initiated with a 5-minute warm-up on a cycle ergometer (Monark Exercise 828E, Vansbro, Sweden), at a self-selected low-intensity (~50-60 rpm), followed by a set of 10 repetitions at 50% of participant's 1-RM followed by either the PE or CHP exercise protocols. The protocols were matched for an equal load volume to allow for potential protocol-specific characteristics to be demonstrated. During both protocols, 2 minutes of rest were allotted between each set. For the PE protocol a metronome was used to control tempo, in which a cadence of 60 b·min-1 was set for 2 seconds eccentric and an explosive concentric movement. All concentric portions of the repetitions were performed "as rapidly and explosively as possible" with one's feet still on the ground, ending in a neutral and non-plantar flexed position. During the CHP protocol, a cadence of 60 b·min-1 was used for a controlled 2 second eccentric and 2 second concentric movement occurred for all repetitions.

Countermovement Vertical Jumps (CMJ): On day one of the study (the familiarization day) countermovement jumps were performed by the participants, and the researcher was there to answer any questions, or critique any incorrect form or attempts. Participants performed two maximal CMJs at each time point with the best jump (based on PP) being used for data analysis. Jump height (cm) was measured based on flight time (ms) of the jump utilizing a jump mat (Just Jump Technologies, Huntsville, AL, USA). Flight time is defined as the amount of time between when the participant's feet left the mat to when the participant's feet returned back on the mat. Additionally, PP, MP, PV, and MV were simultaneously measured during each unloaded jump using a linear position transducer (LPT) (Tendo Sports Machines, Slovak Republic) that was placed directly behind the participant with the nylon string secured to a belt fastened around the participant's waist. Prior to jump testing, each participant's body mass (kg) was measured on a stadium scale (Detecto, Webb City, MO, USA) and entered into the linear transducer microcomputer (Tendo weightlifting analyzer V-207) so that power and velocity output could be measured. Following each jump, MV, PV, MP, and PP were displayed by the microcomputer and were manually recorded. Test-retest reliability determined by intraclass correlation coefficients, SEM, and minimal difference was performed using pretest values from testing days for each dependent variable (Table 3). During each CMJ, participants began in an upright position with feet shoulder width apart and hands positioned on the hips. Previous authors have suggested that attempting to coordinate a rapid arm swing during a VJ may lead to greater within-subject variability and may not be appropriate when measuring the explosive properties of the lower extremity (Markovic et al., 2004). Thus, any rapid/powerful arm swing movements were minimized (hands on hips) in order to limit within-subject variability as well as provide a more uniform assessment. Upon verbal command, participants initiated a downward countermovement followed by a vertical movement as explosively as possibly for all vertical jumps. Each participant was instructed to refrain from tucking their knees while in the air, as this could artificially extend the flight time and ultimately skew the JH data.

Statistical Analysis

All data was analyzed using SPSS version 24.0 (SPSS Inc., Armonk, NY, USA). Separate 2-way repeated measure ANOVAs [Intensity (PE vs. CHP) × Time (Pre vs. S1 vs. S2 vs. S3 vs. S4 vs. S5/Post0] and [Intensity (PE vs. CHP) × Time (Pre vs. S5/Post0 vs. Post5 vs. Post10 vs. Post15 vs. Post20] were run for all dependent variables (PP, MP, PV, MV, and JH). Partial eta squared (ηp2) values were reported to estimate ANOVA effect sizes (0.01 = small; 0.06 = medium; 0.14 = large). In the case of the violation of sphericity Greenhouse-Geisser results were reported. An alpha level of $p \leq 0.05$ was used to determine statistical significance.

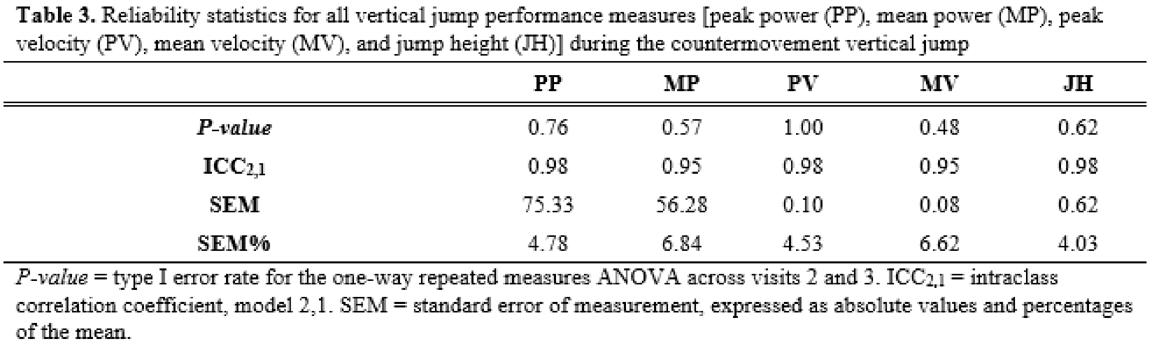

Table 3. Reliability statistics for all vertical jump performance measures [peak power (PP), mean power (MP), peak velocity (PV), mean velocity (MV), and jump height (JH)] during the countermovement vertical jump

	PP	**MP**	**PV**	**MV**	**JH**
P-value	0.76	0.57	1.00	0.48	0.62
ICC$_{2,1}$	0.98	0.95	0.98	0.95	0.98
SEM	75.33	56.28	0.10	0.08	0.62
SEM%	4.78	6.84	4.53	6.62	4.03

P-value = type I error rate for the one-way repeated measures ANOVA across visits 2 and 3. ICC$_{2,1}$ = intraclass correlation coefficient, model 2,1. SEM = standard error of measurement, expressed as absolute values and percentages of the mean.

2.3.3. Results

No significant intensity × time interaction was observed for MP ($p = 0.87$, $\eta p^2 = 0.02$), PP ($p = 0.30$, $\eta p^2 = 0.08$), MV ($p = 0.79$, $\eta p^2 = 0.03$), PV ($p = 0.36$, $\eta p^2 = 0.07$), nor JH ($p = 0.73$, $\eta p^2 = 0.05$). However, main effects for time were observed for all variables; MP ($p \leq 0.001$, $\eta p^2 = 0.52$), PP ($p \leq 0.001$, $\eta p^2 = 0.43$), MV ($p \leq 0.001$, $\eta p^2 = 0.54$), PV ($p \leq 0.001$, $\eta p^2 = 0.43$), and JH ($p \leq 0.001$, $\eta p^2 = 0.65$).

Immediate Performance Responses (Figures 5-7): MP and MV were significantly lower following the completions of S2 through S5/Post0 ($p = 0.001$-0.02) compared to Pre. PP and PV were significantly lower following S1 through S5/Post0 ($p = 0.001$-0.03) time points compared to Pre. Additionally, JH was significantly lower than Pre following S1 through S5/Post0 ($p \leq 0.001$).

Acute Recovery Responses (Figures 5-7): While MP and MV were significantly reduced ($p \leq 0.01$-0.02) immediately following (S5/Post0) the squat protocols, no other recovery time points (Post5-Post20) were significantly different compared to Pre. However, PP and PV were significantly lower at S5/Post0, Post5, Post15, and Post20 ($p \leq 0.001$-0.04), but not at Post10 ($p = 0.17$-0.21), compared to Pre. In addition, while JH was significantly lower than Pre at S5/Post0, Post15, and Post20 ($p \leq 0.001$-0.02), no differences were observed at the Post5 and Post10 ($p = 0.13$-0.25) time points.

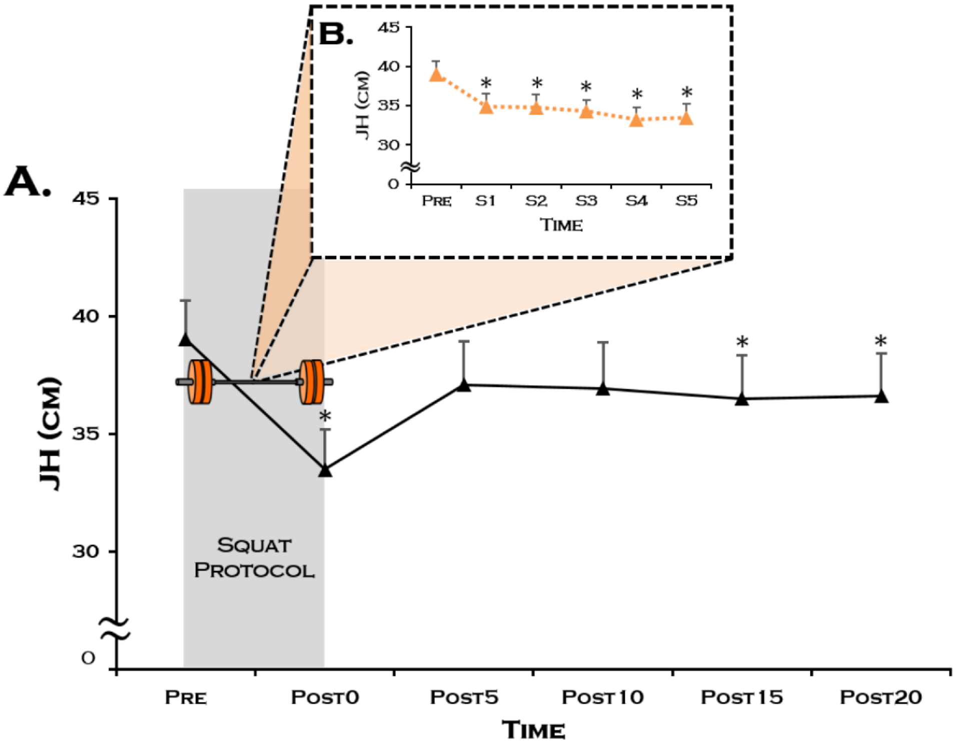

Figure 5. Vertical Jump Height (JH) values (A) before (Pre) and following (Post 0-Post 20) the squat protocols. Vertical JH performance was significantly reduced at Post 0, Post 15, and Post 20 ($p = 0.001$-0.02). Vertical JH values (B) before (Pre) and following each set (S1-S5) of the experimental protocol. JH performance was significantly lower following all protocol sets (S1-S5) compared to Pre ($p = 0.001$). * Indicates significantly lower compared to Pre.

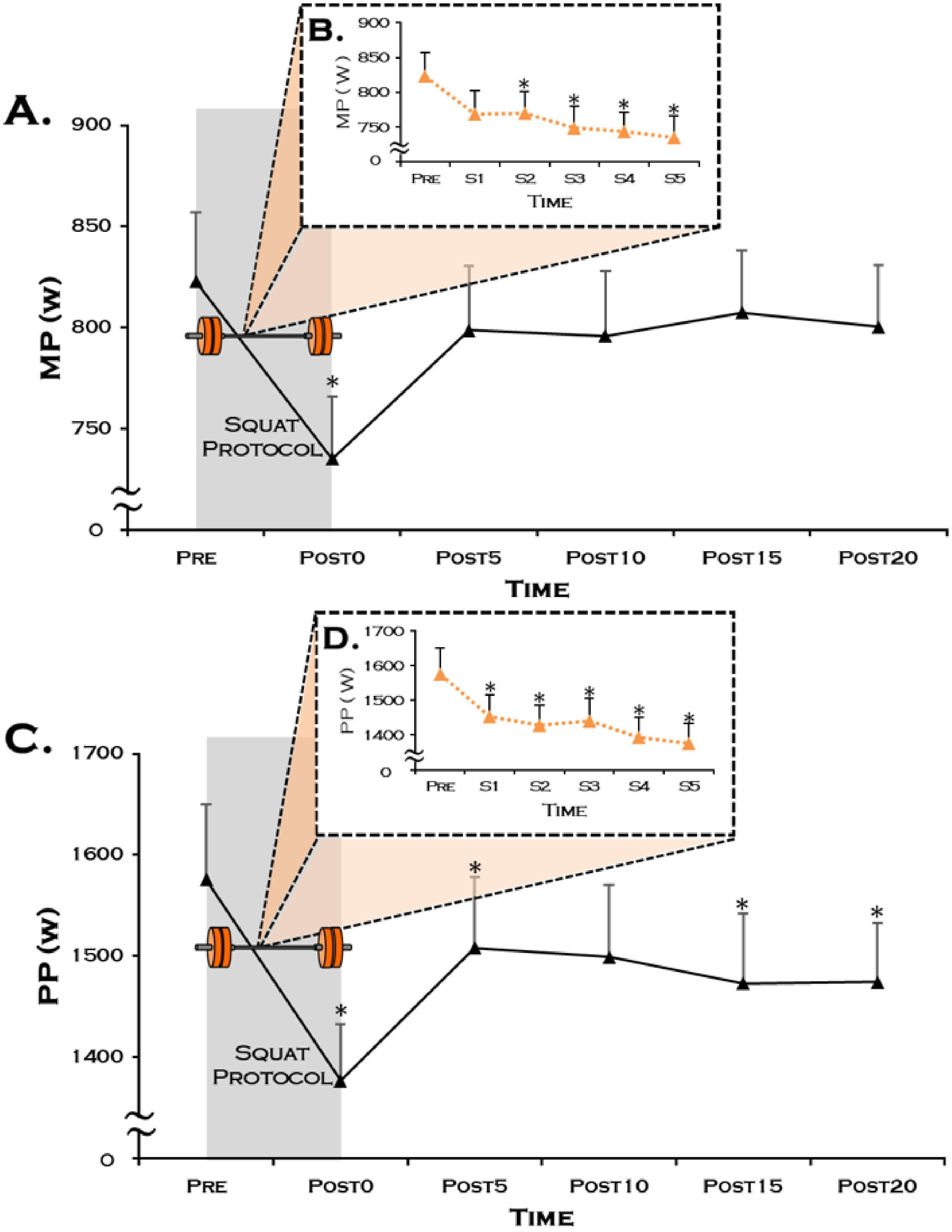

Figure 6. Vertical Jump MP (A) and PP (C) before (Pre) and following (Post 0-Post 20) the squat protocols as well as following individual sets of the experimental protocol (B; D). MP was significantly lower at Post 0 ($p = 0.02$) (A) and following S2-S5 ($p = 0.002$-0.01) (B) compared to Pre. Additionally, PP was significantly lower at Post 0, Post 5, Post 15, and Post 20 ($p = 0.04$) (C) and following all protocol sets S1- S5 compared to Pre ($p = 0.001$-0.03) (D). * Indicates significantly lower compared to Pre.

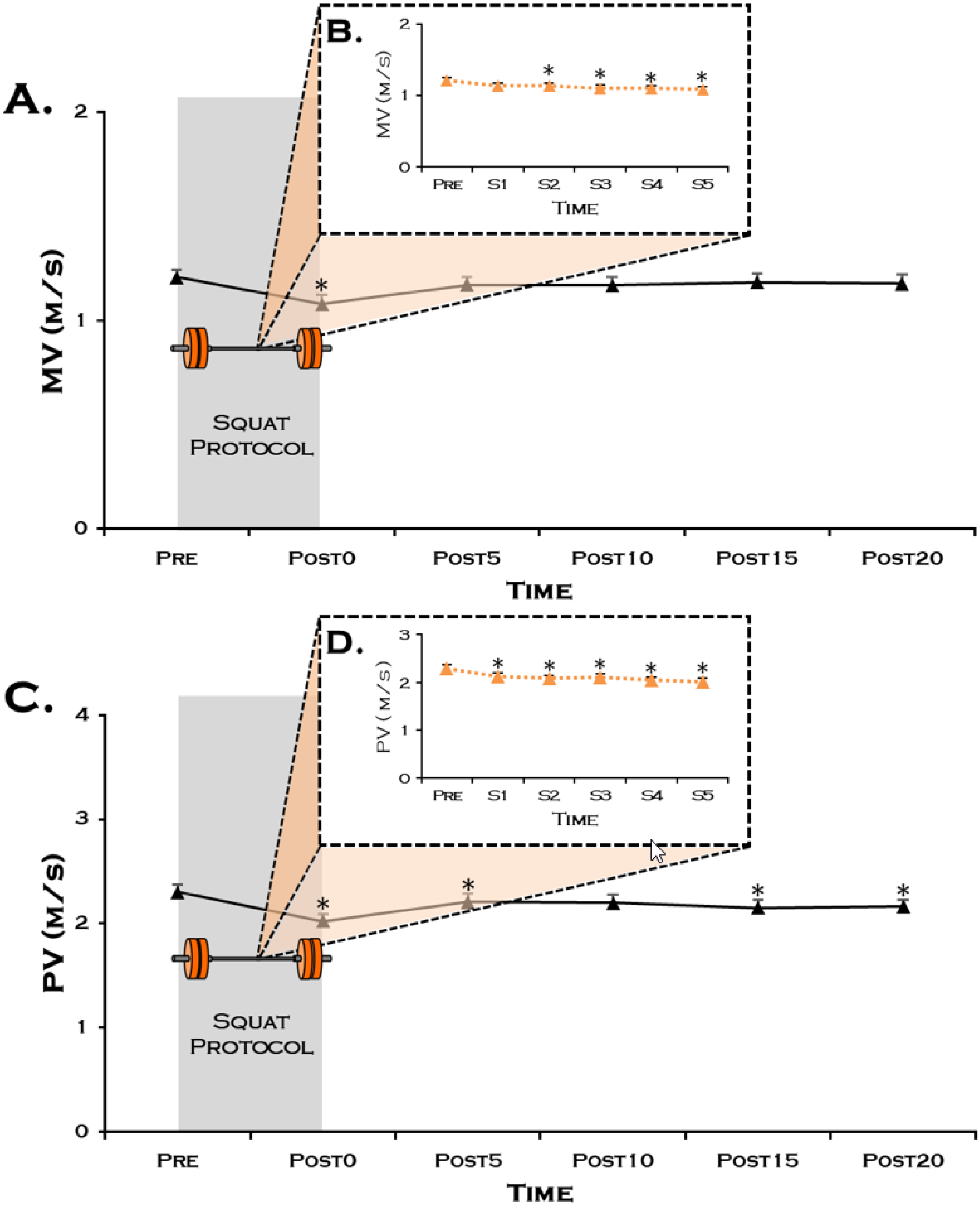

Figure 7. Vertical Jump MV (A) and PV (C) before (Pre) and following (Post 0-Post 20) the squat protocols as well as following individual sets of the experimental protocol (B; D). MV was significantly lower at Post 0 (p = 0.004) (A) and following S2-S5 (p = 0.001-0.02) (B) compared to Pre. Additionally, PV was significantly lower at Post 0, Post 5, Post 15, and Post 20 (p = 0.001-0.02) (C) and following all protocol sets S1- S5 compared to Pre (p ≤ 0.001-0.03) (D). * Indicates significantly lower compared to Pre.

2.3.4. Discussion

The purpose of this investigation was to examine the immediate (within exercise bout) and acute (recovery) vertical jump performance responses following two different volume-matched free-weight back squat exercise protocols. Interestingly, the present study observed no differences between squat conditions (PE; 5×16 at 40% 1-RM vs. CHP; 5×8 at 80% 1-RM). A key finding from the present study was the immediate performance deficits (PP, PV, and JH) after performing only a single set of exercise, regardless of the intensity. However, when assessing acute recovery post-exercise bout, dissimilar recovery responses (partial recovery Post5-Post10) were observed between the performance variables (MP, MV, PP, PV, & JH). Nonetheless, the overall findings revealed decreased performance for 20 minutes post-exercise (Figures 5-7). These results demonstrate how explosive and rapid performance may be negatively impacted after completing one set of a designated exercise, and performance may be decreased up to 20 minutes following the exercise bout.

A novel finding of the present study was the immediate (after one set of squats) decrease in PP (~8%), PV (~7%), and JH (~10%). These variables were further decreased following S5/Post0 by ~13%, ~12%, and ~14%, respectively (Figure 6). In addition, the present study observed a ~7% decrease in both MP and MV following the second set of squats, where both MP and MV were reduced up to ~11% following S5/Post0 (Figure 6 & Figure 7). While several studies have investigated the acute effects (i.e. a single set or bout) of loaded squats (half, back, or jump squats) on vertical jump performance (Hanson et al., 2007; Hester et al., 2017; Jensen and Ebben, 2003; Lowery et al., 2012; Moir et al., 2011; Scott and Docherty, 2004; Smilios et al., 2005; Whitmer et al., 2010), the intended purpose of these studies were to elicit post-activation potentiation responses. Furthermore, while the previous studies included squat based movements within their workout, to the authors knowledge, only two studies assessed vertical jumps directly following loaded back squats (Jensen and Ebben, 2003; Lowery et al., 2012). Nevertheless, in agreement with our findings, Jensen and Ebben (2003) reported a significant decrease in JH for males and females (~11% and ~4%) immediately (10s) after performing a single set of 5-RM back squats. Additionally, Lowery et al. (2012) observed significant decreases in JH and power output directly following volume-matched back squats using moderate (1 × 4 at 70% 1-RM) and high-intensity (1 × 3 at 93% 1-RM) conditions. While the two previous studies only examined vertical jump performance after a single set of squats, Smilios et al. (2005) investigated vertical jump performance across multiple sets with two different loading protocols (moderate loaded jump squats, 3 × 5 with 30-60% of 1-RM, and half squats 3 × 5 with 60% 1-RM). In contrast to the present study, Smilios et al. (2005) observed a significant increase (~4%) in JH after the first and second sets. Differences between the present study's findings and Smilios et al (2005) could be attributed to squat protocols (regular squat vs. jump squats), overall volume (controlled for overall volume vs. non-controlled), intensity (40 and 80% 1-RM, vs. 30-60% 1-RM), rest periods between sets (2 min vs. 3 min), and purpose (assess responses post-sets, vs. potentiation responses). Interestingly, while dissimilar responses were observed post-exercise between these studies, future research may expand on these findings by examining within-set responses and varying intensities as well as exercises within a variety of populations.

An interesting finding from the present study was the similar fatigue- and recovery-related responses between the two squat protocols after controlling for overall training volume. Specifically, the present study observed a significant decrease (~7-14%) in all performance measures following the completion (S5/Post0) of both squat protocols (Figures 5-7). These findings are similar to those of Hester et al. (2017) who reported no difference between a jump squat (10 × 20% 1-RM) or heavy (5 × 80% 1-RM) protocol on vertical jump performance (PP, PV, and JH). In addition, although Hanson et al. (2007) was attempting to elicit potentiation, the authors found no significant differences in kinetic measures (net impulse, time of ground contact, and vertical ground reaction force) for vertical jumping following a low-intensity, fast velocity (1 × 8 at 40% of 1-RM) or high-intensity, slow velocity (1 × 4 at 80% of 1-RM) set of squats. Contrary to our findings, Lowery et al. (2012) observed a significant increase in JH and PP 4-8 minutes following their volume-matched moderate- and high-intensity back squat protocol. Differences between Lowery et al. (2012) and the present study may be related to squat protocols (single set vs. multiple sets) purpose (induce potentiation vs. assess exercise responses) and sex (male vs. female). Interestingly, while the performance measures appeared to start recovering by Post10, PP, PV, and JH were significantly lower at Post15 (~6-7%) and Post20 (~6%) when compared with Pre (Figures 5-7). Similarly, Hester et al. (2017) observed decreases in PP (~5%), PV (~5%), and JH (~4%) measured at 10 minutes following their heavy squat protocol. Thus, taken together, these findings suggest that vertical jump performance can be significantly reduced immediately following a bout of either power-endurance or controlled heavy squat protocols for resistance-trained females.

The immediate and acute decreases in performance for the aforementioned as well as present study may be related to the effects of fatigue. While fatigue is a complex process that may involve both metabolic and neural physiological changes, it is plausible that repetitive repetitions of low- to high-intensity muscular contractions can induce peripheral fatigue. Mechanisms of neuromuscular fatigue have largely been characterized as being peripheral, likely occurring from an inability to restore Na+ (sodium) and K+ (potassium) gradients across the sarcolemma resulting in large amounts of K+ being depleted, thereby leading to impaired action potential conduction efficiency (10). The decreased Ca2+ (calcium) reuptake combined with an inhibition of the t-tubules which reduces sarcoplasmic reticulum calcium release may lead to decreased sensitivity at the cross-bridge binding sites (Fitts, 2006). In addition to peripheral mechanisms, it is plausible that stimulation of group III and IV chemoreceptor afferent neurons may have occurred, which have inhibitory effects on the α-motoneurons innervating the fatigued muscle (Bigland-Ritchie et al., 1986). Although performance deficits (PP, PV, JH) were observed after just a single set of back squats, we acknowledge that acute mechanical or viscoelastic tissue changes (e.g., stiffness, creep, elasticity) may have contributed to immediate alterations to the stretch-shortening cycle (Conchola et al., 2015). Due to the nature of the experimental protocols (controlled tempo during the eccentric phase), it is plausible that even acute bouts of mechanical loading may influence tissue compliance, thus affecting muscle force transmission and decreasing ballistic performance during the countermovement jump. However, while the present study did not directly assess these various physiological characteristics, future research is warranted for assessing the contributions of peripheral mechanisms and viscoelastic alterations on direct performance responses following functional mechanical loading.

The findings of this study revealed that both the power-endurance and controlled heavy squat protocol elicited significant decreases in vertical jump performance for resistance-trained women. Future research should compare different volumes, intensities, and types of exercises (e.g., weighted jumps, box jumps, depth jumps), which have unique stretch-shortening cycle patterns to determine their effects on vertical jump performance. In addition, to properly determine the immediate or direct effects protocols have on vertical jump performance within-set measurements/assessments should be added. While the present investigation included resistance-trained individuals, the recovery responses may greatly differ compared to sedentary or older populations. Furthermore, the present study controlled for overall total volume between the training protocols. While this may be common for recreational and lab-based training, the present exercise protocols may not be applicable across all activity levels.

2.3.5. Conclusions

Knowing that a variety of populations implement compound movements into their resistance training routines, the present findings suggest that vertical jump performance may be negatively affected following a power-endurance or controlled heavy squat protocol. Thus, assessing vertical jump performance variables (PP, MP, PV, MV, and JH) following exercise may be valuable in identifying the immediate and residual consequences of fatigue over an acute recovery period. Furthermore, a recovery period of up to 20 minutes may yield impaired physiological and functional characteristics for individuals who perform tasks similar to the present study. Thus, clinicians, practitioners, and strength and conditioning professionals may use caution when designing lower-extremity exercises, as dynamic/functional characteristics may be diminished after the first set and for an acute period of time (0-20 minutes) post-exercise.

2.4. Mackey, C.S., Thiele, R.M., and DeFreitas, J.M. Effects of fatiguing moderate-velocity muscle actions on isometric and isokinetic performance. *To Be Submitted*, 2020.

2.4.1. Introduction

Fatigue has been defined as any reduction in the force-producing capacity of a muscle during a maximal voluntary contraction (Gandevia, 1992), a reduction in the power-production of the muscle, as well as an inability to maintain a given maximal strength level when performing repeated maximal contractions (Mathiassen, 1989). While decreases in performance may occur post-fatigue, considerable evidence suggests that fatigue is not caused by a single factor, and, that the mechanisms underlying the force reduction are task specific (Enoka, 1992; Gandevia, 2001). For instance, a significant amount of research has been conducted on dynamic fatiguing protocols and acute recovery responses (pre vs. post isometric assessment) (Chiu et al., 2004; Conchola et al., 2015; Klass et al., 2004; Marshall et al., 2012; Walker et al., 2012), however, discrepancies in acute responses from fatigue could be related to the different fatigue interventions that were implemented (overall percent fatigue, repetition scheme, time under tension, etc.). For example, Klass et al. (2004) examined fatigue responses for isometric peak torque of the triceps surae; however, the investigators utilized a dynamic plantar flexion fatigue intervention. Although the authors observed a significant decrease in peak torque for the plantar flexors, they observed a sizable difference (~10% reduction) in torque depending on the angle at which the ankle was tested. The implementation of a dynamic assessment prior to and immediately following their intervention may have elucidated the disparity in the isometric fatigue responses they observed. Additionally, Marshall et al. (2012) investigated the effects of fatiguing squat protocols on maximal isometric force of the squat. While their study revealed a significant decrease in maximal and rapid force, the implementation of a fatiguing isometric squat protocol may have provided additional information about the fatigue response mechanisms for isometric versus dynamic contractions. Furthermore, it is important to note that muscle power has been shown to be negatively affected more than maximal force following a dynamic fatigue protocol (James et al., 1995) and this reduction in force-producing capacity may lead to deficits in subsequent muscular performance, thus hindering physical ability post-exercise. Consequently, assessing multiple modalities may provide different results and may provide more answers about the mechanisms regarding fatigue responses.

Thus, different modes of assessment (e.g., isometric vs. isokinetic) may reveal dissimilar acute deficits in maximal strength and rapid force characteristics following a dynamic fatigue protocol of the upper extremity. Therefore, the purpose of this investigation was to determine if fatiguing, moderate-velocity muscle actions affect isokinetic (dynamic) strength characteristics to a greater extent compared to their isometric (static) strength counter parts. We hypothesized that all post measurements, independent of testing modality, would be significantly reduced with fatigue. However, we anticipated a difference in the magnitude of the decline. Specifically, we hypothesized that the dynamic assessments for strength and acceleration would yield a significantly greater decline following a dynamic, isokinetic fatigue protocol than static, isometric assessments.

2.4.2. Methods

Participants

Twenty-five college-aged, resistance-trained males (mean ± SD: age = 23.2 ± 2.7 years, height = 178.0 ± 6.0 cm, mass = 88.5 ± 10.6 kg) volunteered to participate in this study. All participants reported being consistently engaged in a structured resistance-training program involving the upper body for a minimum of 6 months (mean ± SD: 5.5 ± 3.0 years, 4.7 ± 0.6 days per week) (≥3 times per week) prior to the study. None of the participants reported any current or ongoing musculoskeletal injuries of the upper extremity within the previous 12 months prior to testing. This study was approved by the University Institutional Review Board for human subject's research, and each participant signed an informed consent document and health history questionnaire prior to testing.

Procedures

This study was designed to investigate the effects of an isokinetic protocol on isometric and dynamic fatigue indices (FI%) of the elbow flexors (EF). Each participant visited the laboratory on 2 occasions separated by ~48-72 hours. During the first visit, participants were familiarized with isometric and isokinetic maximal voluntary contractions (MVCs), as well as the experimental fatigue protocol. During the second visit, participants completed isokinetic and isometric MVCs, in a randomized order, of the EF prior to (PRE) and following (POST) 50 isokinetic muscle actions at a controlled angular velocity of $180^{o} \cdot s^{-1}$.

Isometric Strength Assessments

Maximal isometric strength testing was performed on the right arm using a Biodex System 3 isokinetic dynamometer. Participants were seated with restraining straps across the chest and pelvis and the input axis of the dynamometer lever arm was aligned with the axis of rotation of the elbow. Additionally, a Velcro-adjusted elastic band was secured over the upper arm to diminish excessive movement. All isometric torque assessments for the EF were performed with a shoulder angle of 90º in the sagittal plane with an elbow angle of 90º between the arm and forearm (Beck et al., 2012; Bilodeau et al, 2001). Prior to maximal isometric strength testing, the participants performed a 5-minute warm-up on the upper body ergometer at a pre-determined low-intensity (~60 $\text{rev}\cdot\text{min}^{-1}$). In addition, 3 submaximal isokinetic muscle actions were performed at $60^{\circ}\cdot s^{-1}$ with approximately 75% of their perceived maximal effort for the EF. Following the sub-maximal contractions and prior to experimental testing, each participant performed 3 isometric MVCs of the EF with 1 minute of recovery between each contraction. The participants were verbally instructed to 'pull,' "as hard and fast as possible" for a total of 3-4 seconds for all MVCs (Thompson et al., 2013). This process was also repeated immediately following the experimental fatigue protocol.

Velocity Assessments

Similar to the aforementioned maximal isometric testing procedures, maximal velocity (Vmax) testing was performed by setting the isokinetic dynamometer at a velocity of $500^{\circ}\cdot s^{-1}$ (i.e., velocity of the dynamometer was set above all subjects' maximum velocity capacities). Each participant performed 3 isokinetic MVCs through ~90º of ROM for the EF with 1 minute of recovery between each contraction. Vmax was used to assess the maximal shortening velocity of the muscle-limb unit in which no resistance (with the exception of the lever arm) was provided throughout the duration of the contraction (Thompson et al., 2014). The participants were verbally instructed to ‘pull,’ “as fast as possible”. This process was repeated immediately following the experimental fatigue protocol (Aagaard et al., 2000; Thompson et al., 2011).

Fatigue Protocol

Five minutes following all PRE testing, participants performed the experimental fatigue protocol consisting of 50 continuous repetitions of isokinetic contractions of the EF at 180º·s^{-1} (medium velocity) through ~90º ROM (Beck et al., 2005). Participants were seated with restraining straps identical to all MVC testing procedures. Additionally, a neutral handgrip, with the elbow secured to the arm pad (using a flexible velcro band/strap), was used in order to perform elbow flexion throughout the protocol. During the experimental protocol, participants were asked to provide maximal effort for each muscle action and were verbally encouraged to ‘pull’, as hard as they can throughout the entire protocol. Experimental testing was terminated at the completion of all 50 maximal repetitions. Verbal encouragement was provided to the participants during the entire protocol. Immediately following (within 10 s) the fatigue protocol MVC assessments were repeated.

Signal Processing

Torque (N·m) and angular velocity (deg·s^{-1}) signals were sampled simultaneously at 2 kHz with a Biopac data acquisition system, stored on a personal computer, and processed off-line with custom-written software. The torque signal was smoothed using a 25 ms zero-shift moving average. All subsequent analyses were performed on the scaled and filtered torque signal. Isometric MVC peak torque (PT) was determined as the highest 25 ms epoch during the entire 3–4 s MVC plateau (Thompson et al., 2013;

Conchola et al., 2013). Isokinetic PT was attained from the first and last 3 reps of the fatigue protocol. Absolute RTD was calculated from the linear slope of the torque-time curve (Δtorque/Δtime) across the interval of 0-50 ms. Vmax ($deg \cdot s^{-1}$) was calculated as the highest velocity attained during the unloaded MVC ($500^o \cdot s^{-1}$). Maximum acceleration (ACCmax) ($deg \cdot s^{-2}$) was determined as the 10 ms interval that demonstrated the highest linear slope of the velocity-time curve (Δvelocity/Δtime) from the Vmax contraction (See Figure 8.). These procedures were used to obtain the linear portion of the rate of rise in velocity, while simultaneously excluding the deceleration or "rounding off" of the signal observed at the edge of the velocity plateau. The onset of velocity was determined as the point when the velocity signal reached a threshold 2 $deg \cdot s^{-1}$ above baseline (Thompson et al., 2014). The isometric MVC with the highest PT and RTD were used for all analyses. Isokinetic $180° \cdot s^{-1}$ FI% was calculated using initial and final PT, which consisted of the average of the three muscle actions with the highest and lowest PT values during the fatigue protocol, respectively. All fatigue indices were calculated as "(Final – Initial) ÷ Initial × 100".

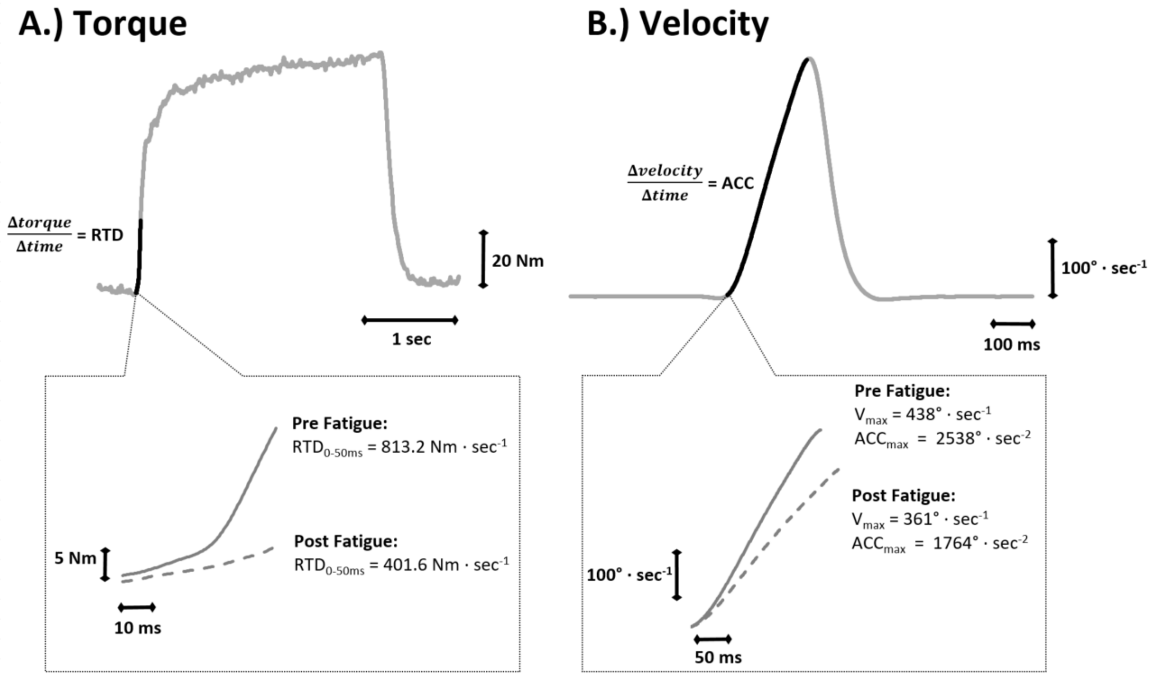

Figure 8. Example measures pre- and post-fatigue. Plot A shows an example torque signal during an isometric maximal voluntary contraction (MVC). The darker section of the signal highlights the 50 ms epoch used to assess rate of torque development (RTD). The subplot below shows the 50 ms epoch magnified (note the different axis scales) for both the pre-fatigue MVC as well as the post-fatigue MVC from the same subject. Plot B shows an example velocity signal during a dynamic, unloaded MVC (pre-fatigue). The darker section of the signal highlights the onset of movement to peak velocity (Vmax). This highlighted epoch is magnified in the subplot below, and again shows both a pre-fatigue and post-fatigue MVC for the same subject. Acceleration was calculated with a 10 ms moving window, and the highest 10 ms value was considered the peak acceleration (ACCmax).

Statistical Analysis

Four separate paired samples t-tests were used for each dependent variable (PT, RTD, ACCmax, and FI%). Pearson correlation coefficients were computed to assess the relationships between FI% for each dependent variable. PASW software version 21.0 was used for all statistical analyses. An alpha level of $p \leq 0.05$ was considered significant for all comparisons.

2.4.3. Results

Paired Samples t-tests

Means, standard deviations, and distributions for all dependent variables FI% are presented in Figure 9. Isometric PT FI% (M = -18.71, SD = 8.38) was significantly lower than isokinetic PT FI% (M = -45.08, SD = 8.87; $p \leq 0.001$). Additionally, ACCmax FI% (M = -26.27, SD = 8.82) was significantly less than isometric RTD FI% (M = -54.89, SD = 11.48; $p \leq 0.001$). Each of the four dependent variables (isometric PT, isokinetic PT, isometric RTD, and ACCmax) observed significant decreases with fatigue (all four demonstrated $p < 0.001$).

Pearson Correlation Coefficients

There was a significant positive relationship between isometric PT FI% and isokinetic PT FI% ($r = 0.60$, $p < 0.002$) as well as between isometric PT FI% and isometric RTD FI% ($r = 0.40$, $p < 0.046$). There was no significant relationship observed between isometric RTD FI% and ACCmax FI% nor between isokinetic PT FI% and ACCmax FI% (See Figure 10).

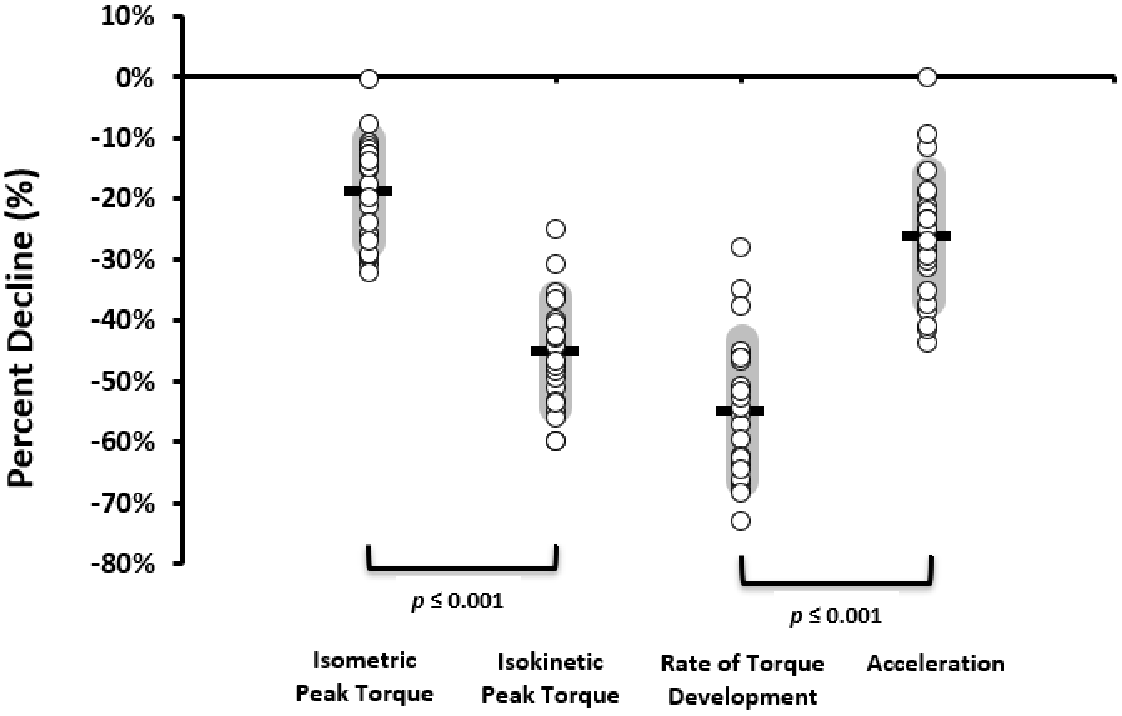

Figure 9. Distribution plot showing individual responses to fatigue for the four dependent variables. Each circle represents an individual subject's data point. The horizontal black line is the mean, and the shaded areas depict the standard deviations. The brackets denote significant difference between variables ($p \leq 0.001$).

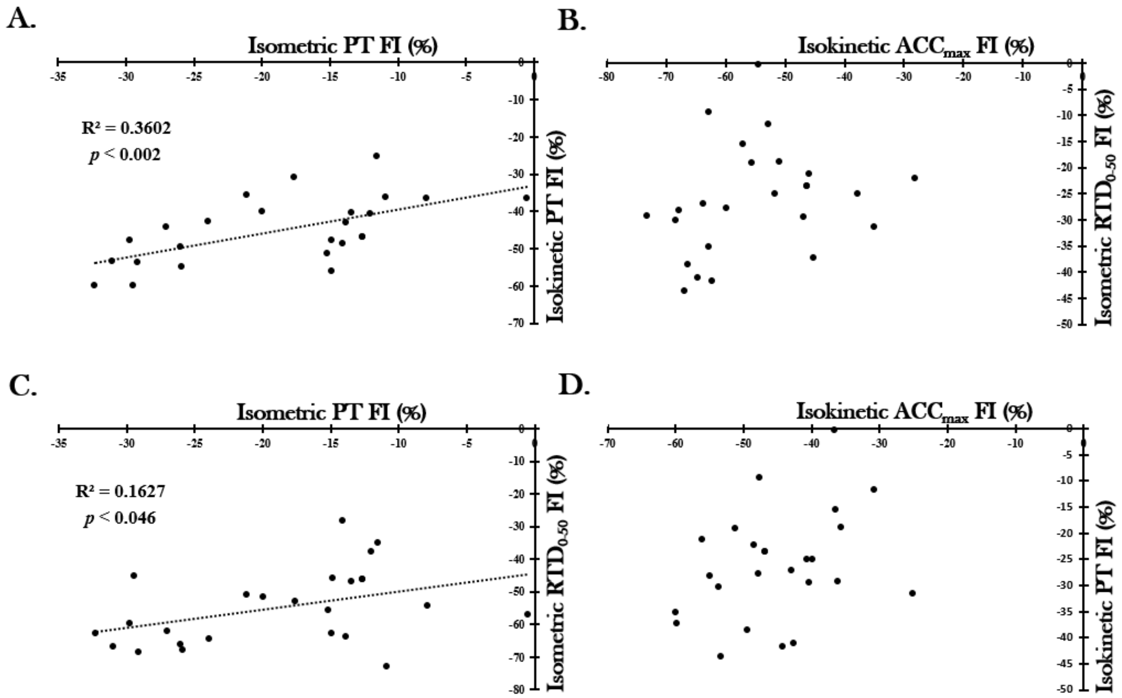

Figure 10. Correlations between the four dependent variables. Trend lines are shown only for the significant relationships ($p < 0.05$). PT = peak torque, FI = fatigue index, ACCmax = peak acceleration, RTD = rate of torque development.

2.4.4. Discussion

The primary findings of the present study revealed different acute responses between isometric PT FI% and isokinetic PT FI% following a dynamic fatiguing isokinetic protocol (Figure 9). While different muscles were assessed (quadriceps), the present study's findings for isometric (18.71%) and isokinetic PT (45.08%) fatigue responses are similar to James et al. (1995) who reported (25% vs. 50%) reductions respectively. An important difference between isometric and isokinetic contractions are the overall production of work (Motzkin et al., 1991). Motzkin et al. (1991) suggested that there is a distinct difference in the physiologic mechanisms of fatigue between contractions that produce work and those that do not (i.e. isometric), and that this difference accounts for the dissimilarity between isometric and isokinetic FI%.

Specifically, James et al. (1995) proposed the differences in fatigue between the two modes of contraction may be related to the slowing of the contractile properties of the muscle, which is common with fatigued muscles. These responses may be attributed to a slower turnover of cross-bridge cycling rates, which may negatively affect shortening velocity and power output, thus, creating larger deficits in isokinetic compared to isometric force production (Haan et al., 1989; Jones and Bigland-Ritchie, 1986).

Deficits in maximal and rapid torque characteristics as well as ACC have commonly been observed following bouts of isokinetic exercise. In agreement, the present study observed a significant decrease in ACC for the EF immediately following the moderate-velocity protocol. These findings are similar to Nguyen et al. (2009), who reported a significant decrease in EF ACC ($240^{\circ}\cdot s^{-1}$) immediately following an isokinetic eccentric protocol (6 sets of 10 repetitions at $30^{\circ}\cdot s^{-1}$). The acute response for ACCmax for the EF post-fatigue (26.27% declined) could be attributed to muscle fiber type, since the biceps brachii have been reported to be fast-twitch (FT) dominant (57.7%) (Bellemare et al., 1983). Thus, the immediate fatigue-related deficits for ACCmax may be attributed to greater fatigue for the FT muscle fibers in the biceps brachii. In addition, RTD also observed a significant decrease post-fatigue (54.89%). The immediate deficits in rapid strength may be attributed to cross-bridge cycling rates, muscle fiber type, and calcium kinetics (Aagaard et al., 2002; Andersen et al., 2010; Bottinelli et al., 1996; Brody, 1976; Larsson and Moss, 1993). Unexpectedly, ACCmax displayed a significantly lower fatigue index than RTD, which was in contradiction of our initial hypothesis. In order to examine this disparity, we normalized RTD to peak torque. However, the normalized RTD FI% (44.53%), although reduced by ~10% from absolute RTD, was still significantly higher than the ACCmax FI% ($p \leq 0.001$). Thus, taken together, these findings suggest that an isokinetic dynamic fatigue protocol (50 maximal repetitions at $180^{o} \cdot s^{-1}$) may decrease maximal strength and rapid force capacities to a greater extent compared to acceleration.

While the present investigation observed a dissimilar fatigue response between maximal strength, rapid strength characteristics and acceleration, the overall declines in performance may be due to the effects of peripheral fatigue as a consequence of high-intensity muscular contractions from the dynamic isokinetic protocols (James, 1995). Fatigue is a complex process that may involve both metabolic and neural physiological changes. Mechanisms of neuromuscular fatigue have largely been characterized as being peripheral, likely occurring from an inability to restore Na^{+} and K^{+} gradients across the sarcolemma resulting in large amounts of K^{+} being depleted, thereby leading to impaired action potential conduction efficiency (Green, 1997). Additionally, metabolic by-product buildup from increases of inorganic phosphate, ADP, AMP, and H^{+} could affect the ATPase activity and thus decrease the reuptake of Ca^{2+} (Fitts, 2006). The decreased Ca^{2+} reuptake combined with an inhibition of the t-tubules, which reduces sarcoplasmic reticulum calcium release, may lead to decreased sensitivity at the cross-bridge binding sites (Fitts, 2006). Furthermore, it is possible that increases in acidity levels resulting from the numerous amount of maximal voluntary muscular contractions, may lead to reduced rates of glycogenolysis and creatine phosphate resynthesis (Tesch et al., 1986) as well as stimulation of group III and IV chemoreceptor afferent neurons which have inhibitory effects on the α-motoneurons innervating the fatigued muscle (Bigland-Ritchie et al., 1986). Taken together, these fatigue-related physiological alterations may be a contributing factor to the immediate responses for strength and rapid force characteristics. Future studies should look to incorporate such measures as electromyography, dynamic musculoskeletal ultrasonography, and near-infrared spectroscopy to provide further insight into the effects of fatigue on neurological and muscular properties.

2.4.5. Conclusions

In summary, the present investigation observed dissimilar patterns of response in maximal strength between isometric and dynamic assessments following an isokinetic fatigue protocol. Additionally, the ability to generate strength and velocity rapidly (i.e., RTD and ACC) had significantly different responses to fatigue between isometric and dynamic assessments. Specifically, the deficit observed for isokinetic PT (~45%) was more than double that seen with the isometric PT (~19%). Conversely, the deficit observed for isometric RTD (~55%) was more than double that seen with the dynamic ACCmax (~26%). This demonstration could indicate that the differences in sensitivity of the two types of contractions is a major factor accounting for the loss of force and power during exercise. As previously stated, this may be due to the amount of work produced and/or slowing of the contractile properties of the muscle. Thus, it is important that studies utilizing a fatiguing intervention include testing in the same modality as the fatiguing protocol. Knowing that a number of investigators implement various fatigue modalities, the present findings suggest that pre- and post-isometric and dynamic assessments may vary greatly depending on the type of contractions used during the fatiguing protocol.

The findings of the present investigation could have practical and clinical relevance. Due to the results observed in this study, coaches, trainers, clinicians and practitioners who utilize fatigue resistance as an evaluation tool for recovery following training, injury, or surgery may consider implementing a task specific assessment. Thus, clinicians, practitioners, and strength and conditioning professionals may use caution designing, implementing, and assessing fatigue interventions, as maximal strength and velocity characteristics may reveal differential results depending on the type of contraction utilized.

2.5. **Mackey, C.S.** and DeFreitas, J.M. (2019). A longitudinal analysis of the U.S. Air Force Reserve Officers' Training Corps physical fitness assessment. *Military Medical Research*. https://doi.org/10.1186/s40779-019-0219-4.

2.5.1. Introduction

Physical fitness is important for general health and the ability to perform activities of daily living and occupational tasks. In military services, higher levels of physical fitness are vital for limiting modifiable risk factors (e.g., obesity and risk of injury), improving military task-specific performance, and preventing injuries. Thus, sufficient levels of physical fitness are emphasized in military personnel due to the high physical demands during military training and in warfare (Knapik et al., 1990). In a military context, the term "physical fitness" is predominantly identified as muscular strength, muscular endurance, cardio-respiratory endurance, and body composition (Knapik et al., 2006). However, the importance of each of these components may vary between different types or branches of services. For example, the U.S. Army physical fitness components (a 2-mile run, 2 minutes of pushups, and 2 minutes of sit-ups) are worth up to 100 points each; the scores of each component are summed together and then compared to an overall score of 300 (U.S. Department of the Army, 2013). Currently, the U.S. Air Force uses Air Force Instruction (AFI) 36–2905 to conduct its fitness test, which consists of 1 minute of pushups, 1 minute of sit-ups, an abdominal circumference measurement (inches), and a 1.5-mile run (Department of the Air Force, 2013). However, unlike the U.S. Army, the U.S. Air Force does not weight each component equally. Rather, an airman receives up to 60 points for the run, 20 points for the abdominal circumference measurement, and 10 points each for the sit-up and pushup components.

The U.S. Air Force Reserve Officers' Training Corps (ROTC) program is designed to recruit, educate and commission officer candidates through college campus programs based on the U.S. Air Force requirements. The ROTC program prepares the cadets to become U.S. Air Force officers while earning a college degree. At this time, the ROTC acts as the largest commissioning source among all military branches, and the Air Force ROTC program is offered at more than 1,100 colleges and universities across the U.S. To join the ROTC during college, students enroll in in the ROTC course as they would enroll in any other course. Throughout the program, the students must adhere to the ROTC rules/guidelines and pass the physical fitness assessments each semester. Students can add/drop the ROTC program at any time. However, after students' second year in the program, they must be selected to complete field training. Upon completion of field training, cadets are then offered a contract for a stipend during their final two years and commission once they have finished the program. U.S. Air Force ROTC programs are designed to physically prepare cadets for the demands of a military career. As a result, an important element of the ROTC experience is physical training (PT), which is meant to enhance physical fitness, develop discipline, and provide a unifying experience (Thomas et al., 2004). Specifically, PT is incorporated as a part of the U.S. Air Force culture to establish an environment for members to maintain physical fitness and health and meet expeditionary mission requirements (Department of the Air Force, 2013). For this reason, an effective assessment of physical fitness is necessary to determine if the PT has resulted in improvements over the duration of the ROTC program (American College of Sports Medicine, 1998). Currently, U.S. Air Force ROTC cadets are required to participate in PT two times per week. These mandatory PT sessions consist of a warm-up (stretching and calisthenics), upper- and lower-body strengthening exercises, and running. While there are researches investigated the physical fitness of U.S. Army ROTC cadets (Thomas et al., 2004; Crombie et al., 2012; Gist et al., 2015; Jones et al., 2012; Liguori et al., 2012; Schiotz et al., 1998; Steed et al., 2016; Crawley et al., 2015), but there is a scarcity of research regarding the U.S. Air Force ROTC population. Therefore, the purpose of this investigation was to longitudinally examine U.S. Air Force ROTC cadets over a four-year period for the evaluation of potential differences between class rank within the ROTC utilizing the current physical fitness assessment (PFA) and for the evaluation of the sensitivity of the classification of the tests in terms of absolute test results and composite scores. We hypothesized that PFA performance scores would increase with years in the program (i.e., more PT and experience with the PFA).

2.5.2. Methods

Experimental procedure

Collected data were gathered for analysis from the university U.S. Air Force ROTC program. PFA scores were recorded from two separate classes, one starting in the spring of 2014 and the other starting in the fall of 2014, and then the scores were compiled over a four-year period. The fall and spring groups were then measured/tracked across all four years to assess whether the PFA scores improved during the students' time in the ROTC program. In addition, the time point at which the largest number of cadets took the PFA [fall 2015; N = 46; freshman (n = 8) vs. sophomore (n = 12) vs. junior (n = 17) vs. senior (n = 9)] was examined to evaluate potential differences between class ranks.

Subjects

Male U.S. Air Force ROTC cadets from the spring (n = 26) and fall (n = 22) classes (mean ± SD: age 19.8 ± 1.2 years; height 178.1 ± 5.4 cm; weight 74.9 ± 7.7 kg; body mass index 23.4 ± 2.0) performed the PFA (body composition evaluation, 1 minute of pushups, 1 minute of sit-ups, and a 1.5-mile run) each year for four years. Only the cadets who completed all four years of the program were included in the analysis. Cadets participated in mandatory PT sessions twice per week, which generally consisted of a warm-up, pushups, pull-ups, sit-ups, and running. The university institutional review board for human subject research approved this study. This study was exempt from the consent process because the data included in this study were previously archived (i.e., retroactive) and deidentified (ED-18-39 STW IRB).

Procedures – U.S. Air Force Physical Fitness Assessment

The officers and noncommissioned officers conducted the field-based tests according to Air Force Instruction 36-2905 as part of the usual program assessment practices (Department of the Air Force, 2013). Body composition was the first component assessed, followed by the timed pushups, sit-ups, and 1.5-mile run. A standard rest period of 3 minutes was enforced between components.

Body composition

Body composition included height, weight, and abdominal circumference measurements (inches). However, only the abdominal circumference measurement was used for the body composition component score. For each measurement, the cadets stood stationary while the tester conducted the measurement; the tester started at the superior border of the iliac crest of a cadet and moved around the cadet to place the tape in a horizontal plane around his or her abdomen. The tester took three measurements, and the average of the measurements was recorded for the abdominal circumference score. Cadets remained in the Air Force physical training attire (t-shirt, shorts and/or pants) for the duration of the body composition assessments.

Timed pushups

Cadets performed pushups starting in the "up" position, in which the hands were placed slightly wider than shoulder-width, the palms or fists were placed on the floor, the arms were fully extended, and the rigid hip and spinal posture was maintained. On command, the cadets would bend their elbows and lower their entire body as a single unit until their upper arms were at least parallel with the ground (elbows bent at 90 degrees). The cadets returned to the starting position by raising their entire body until their elbows were fully extended. Any deviation from this form by a cadet resulted in the attempt not being counted toward the cadet's component score. Cadets performed continuous pushups for 1 minute, and the results were recorded.

Timed sit-ups

Cadets performed sit-ups by starting on their back with their knees bent at a 90-degree angle and their feet or heels in contact with the floor. A partner held the cadet's feet with his or her hands, applying adequate pressure across the dorsum of the foot to keep the heels anchored to the floor. The heels were required to remain in contact with the ground throughout the test. With their arms crossed over their chest and their hands/fingers placed on their shoulders or upper chest, cadets performed a complete repetition when they rose from the down position (i.e., upper torso is raised from the floor/mat) until their elbows touched their knees or thighs and then returned to the down position so that their shoulder blades touched the floor/mat. Any deviation from this form resulted in the attempt not being counted. Cadets performed continuous sit-ups for 1 minute, and the results were recorded.

1.5-Mile run

Cadets gathered at a 400-m track and were briefed about the purpose and organization of the test. An officer or noncommissioned officer then used a stopwatch to time each cadet as he completed the 1.5-mile run. The total time (s) was recorded. A standardized set of instructions was read to the cadets (Department of the Air Force, 2013):

“This 1.5 mile timed run is used to measure cardio-respiratory fitness. Prior to beginning the 1.5 mile run, you may complete up to a 3-minute warm-up. You will line up behind the starting line and will be instructed to begin running as I start the stopwatch. No physical assistance from anyone or anything is permitted. Pacing is permitted if there is no physical contact and is not a hindrance to other runners. You are required to stay on and complete the entire marked course. Leaving the course is disqualifying and terminates the test. Your completion time will be recorded when you cross the finish line and you are required to complete a cool down for approximately 5 minutes. If at any time you are feeling in poor health, you are to stop running immediately and you will be given assistance.”

Statistical analyses

One-way repeated measures ANOVA was performed separately for the fall (n = 22) and spring (n = 26) groups for each dependent variable (pushups, sit-ups, abdominal circumference, run time, and composite score) across the 4 years. One-way between groups ANOVA was performed for each dependent variable during the time point (fall 2015; N = 46) with the most recorded cadets for each class rank [freshman (n = 8) vs. sophomore (n = 12) vs. junior (n = 17) vs. senior (n = 9)]. When sphericity was violated, Greenhouse-Geisser results were reported. Partial eta squared (ηp^2) values were reported to estimate ANOVA effect sizes. PASW software (version 23.0, SPSS Inc., Chicago, IL, USA) was used for all statistical analyses. An alpha level of $P \leq 0.05$ was considered significant for all comparisons.

2.5.3. Results

Longitudinal assessment

For the fall semester measurements (Table 4; Figure 11), there was a significant main effect of time ($P = 0.010$, $\eta p^2 = 0.187$) on abdominal circumference; the cadets had a smaller measurement in their freshman year [mean (M) = 31.64, standard error of mean (SEM) = 0.425] than in their senior year (M = 33.23, SEM = 0.306; $P = 0.026$). In addition, a significant main effect of time ($P = 0.006$, $\eta p^2= 0.180$) on sit-ups was observed; students in their junior year (M = 60.96, SEM = 0.979) completed significantly more sit-ups than students in their freshman year (M = 54.96, SEM = 1.459; $P = 0.006$). However, no significant main effect of time was observed on pushups ($P = 0.076$, $\eta p^2 = 0.112$), run time ($P = 0.665$, $\eta p^2 = 0.021$), or the composite score ($P = 0.73$, $\eta p^2 = 0.020$). For the spring semester measurements (Table 5; Figure 11), no significant main effect of time was observed on abdominal circumference (P = 0.188, ηp^2 = 0.064), pushups (P = 0.458, ηp^2 = 0.034), sit-ups (P = 0.261, ηp^2 = 0.052), run time (P = 0.659, ηp^2 = 0.017), or the composite score (P = 0.263, ηp^2 = 0.052).

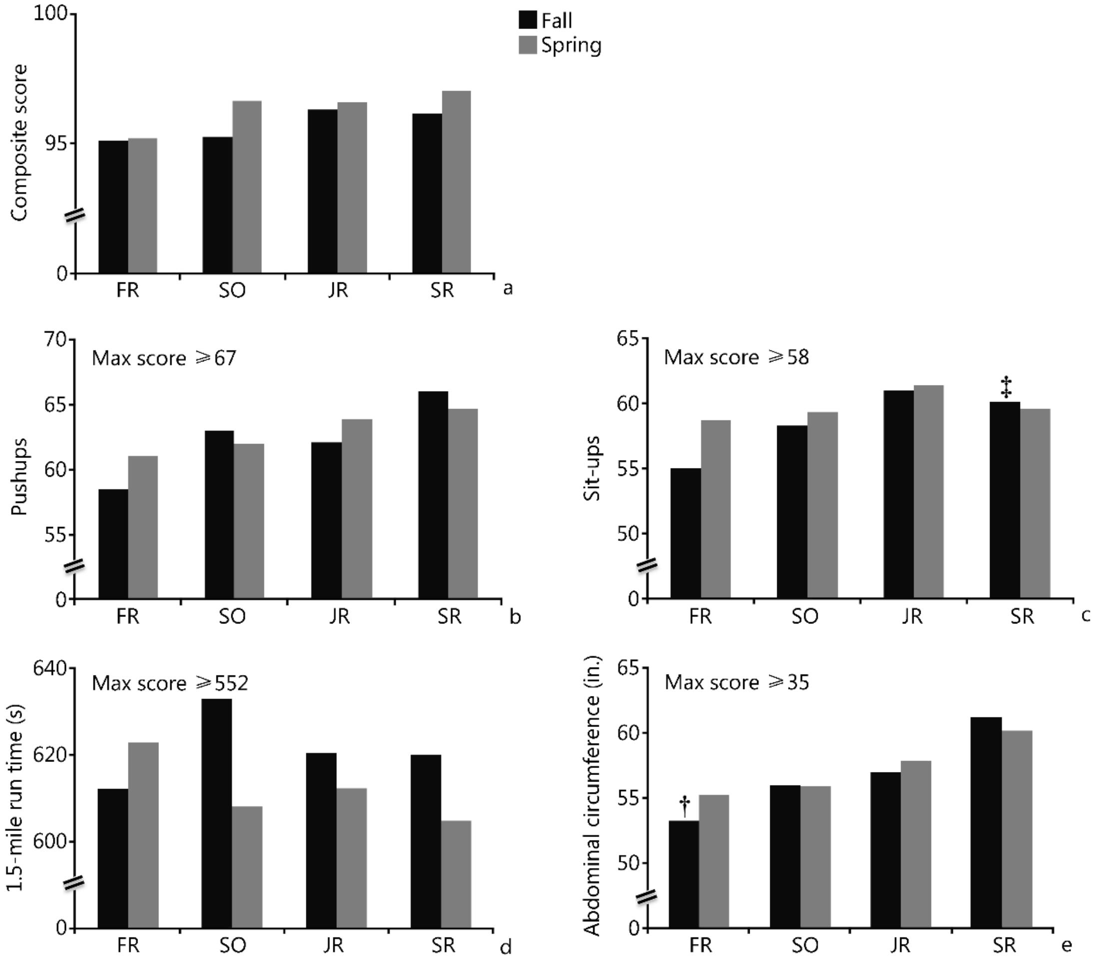

Figure 11. Longitudinal assessment of the freshman (FR), sophomore (SO), junior (JR), and senior (SR) class ranks of two classes (fall class = black; spring class = gray) over four years; the figures are separated by each component of the U.S. Air Force physical fitness assessment. Maximum scores are labeled according to AFI 36-2905. † Significantly different from senior year (P = 0.026). ‡ Significantly different from freshman year (P = 0.006).

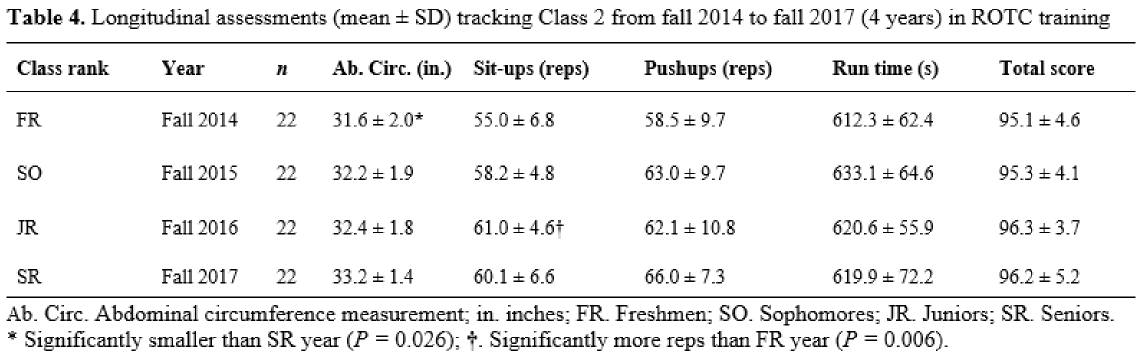

Table 4. Longitudinal assessments (mean ± SD) tracking Class 2 from fall 2014 to fall 2017 (4 years) in ROTC training

Class rank	Year	*n*	Ab. Circ. (in.)	Sit-ups (reps)	Pushups (reps)	Run time (s)	Total score
FR	Fall 2014	22	31.6 ± 2.0*	55.0 ± 6.8	58.5 ± 9.7	612.3 ± 62.4	95.1 ± 4.6
SO	Fall 2015	22	32.2 ± 1.9	58.2 ± 4.8	63.0 ± 9.7	633.1 ± 64.6	95.3 ± 4.1
JR	Fall 2016	22	32.4 ± 1.8	61.0 ± 4.6†	62.1 ± 10.8	620.6 ± 55.9	96.3 ± 3.7
SR	Fall 2017	22	33.2 ± 1.4	60.1 ± 6.6	66.0 ± 7.3	619.9 ± 72.2	96.2 ± 5.2

Ab. Circ. Abdominal circumference measurement; in. inches; FR. Freshmen; SO. Sophomores; JR. Juniors; SR. Seniors.
* Significantly smaller than SR year (*P* = 0.026); †. Significantly more reps than FR year (*P* = 0.006).

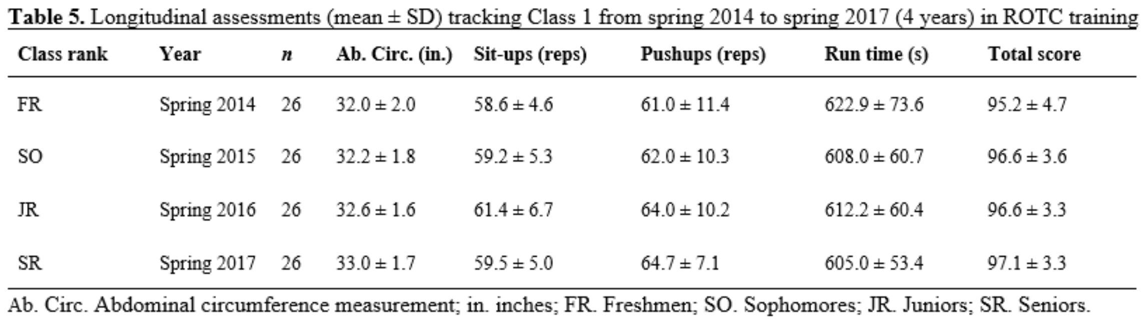

Table 5. Longitudinal assessments (mean ± SD) tracking Class 1 from spring 2014 to spring 2017 (4 years) in ROTC training

Class rank	Year	*n*	Ab. Circ. (in.)	Sit-ups (reps)	Pushups (reps)	Run time (s)	Total score
FR	Spring 2014	26	32.0 ± 2.0	58.6 ± 4.6	61.0 ± 11.4	622.9 ± 73.6	95.2 ± 4.7
SO	Spring 2015	26	32.2 ± 1.8	59.2 ± 5.3	62.0 ± 10.3	608.0 ± 60.7	96.6 ± 3.6
JR	Spring 2016	26	32.6 ± 1.6	61.4 ± 6.7	64.0 ± 10.2	612.2 ± 60.4	96.6 ± 3.3
SR	Spring 2017	26	33.0 ± 1.7	59.5 ± 5.0	64.7 ± 7.1	605.0 ± 53.4	97.1 ± 3.3

Ab. Circ. Abdominal circumference measurement; in. inches; FR. Freshmen; SO. Sophomores; JR. Juniors; SR. Seniors.

Between-subjects assessment

The between-subjects ANOVA (across classes at the same time point; fall 2015) revealed a significant main effect of class rank on sit-ups (P = 0.003); the freshman class (M = 51.25, SEM = 2.63) completed significantly fewer repetitions than both the sophomore class (M = 59.25, SEM =1.01; P = 0.018) and the junior class (M = 60.82, SEM = 1.09; P = 0.001) did. However, no significant main effects of class rank were observed on abdominal circumference (P = 0.286), pushups (P = 0.723), run time (P = 0.486), or the composite score (P = 0.210; Table 6; Figure 12).

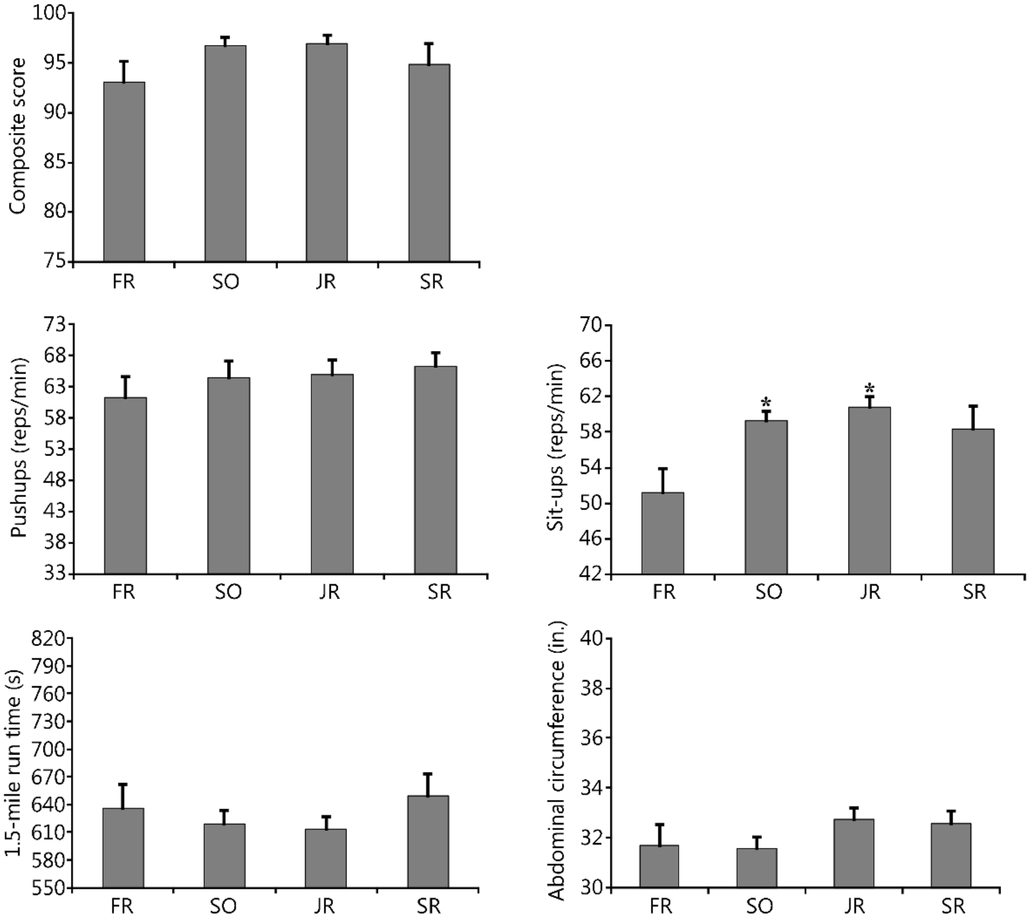

Figure 12. Between-subjects assessment (fall 2015 classes compared between each other) between freshman (FR), sophomore (SO), junior (JR), and senior (SR) class ranks for each component of the U.S. Air Force physical fitness assessment. * Significantly different from freshman year (P = 0.001).

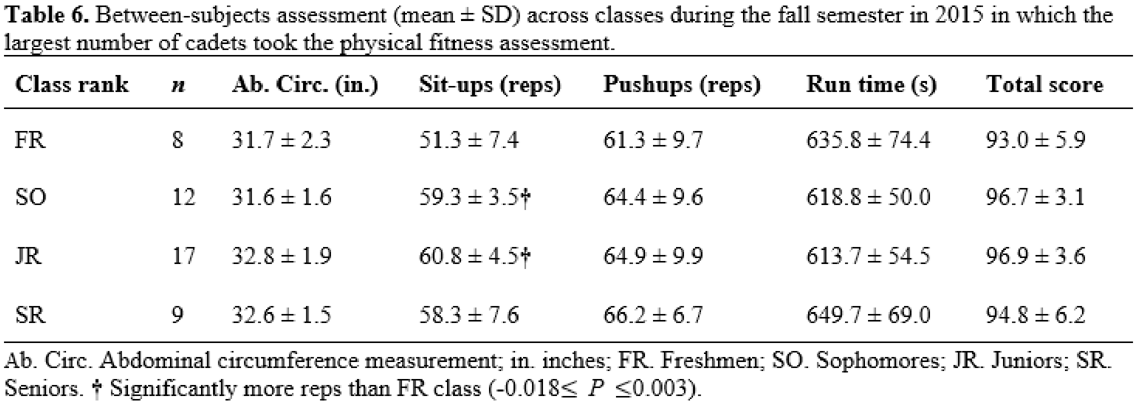

Table 6. Between-subjects assessment (mean ± SD) across classes during the fall semester in 2015 in which the largest number of cadets took the physical fitness assessment.

Class rank	*n*	Ab. Circ. (in.)	Sit-ups (reps)	Pushups (reps)	Run time (s)	Total score
FR	8	31.7 ± 2.3	51.3 ± 7.4	61.3 ± 9.7	635.8 ± 74.4	93.0 ± 5.9
SO	12	31.6 ± 1.6	59.3 ± 3.5†	64.4 ± 9.6	618.8 ± 50.0	96.7 ± 3.1
JR	17	32.8 ± 1.9	60.8 ± 4.5†	64.9 ± 9.9	613.7 ± 54.5	96.9 ± 3.6
SR	9	32.6 ± 1.5	58.3 ± 7.6	66.2 ± 6.7	649.7 ± 69.0	94.8 ± 6.2

Ab. Circ. Abdominal circumference measurement; in. inches; FR. Freshmen; SO. Sophomores; JR. Juniors; SR. Seniors. † Significantly more reps than FR class ($-0.018 \leq P \leq 0.003$).

2.5.4. Discussion

The primary finding of the present investigation was a lack of improvement in most of the variables measured during the longitudinal assessment. These findings raise into question whether the U.S. Air Force PFA is sufficiently sensitive to identify physical training-induced changes or the effectiveness of the current PT regimen. Specifically, this result could be due to how PT is administered (i.e., only training toward the testing standards). However, the fact that these PFAs generally took place later in the semester (i.e., fall testing occurred in November and spring testing occurred in April) may also be a factor. A study performed by Crawley et al. (2015) lends support to this notion, in which the authors found that throughout a 16-week training program with police academy cadets, the cadets showed significant improvements in physical fitness characteristics in only the first 8 weeks. None of the variables they assessed (hand grip, arm crank, Wingate, body composition, 40-yard dash, 1-repetition maximum bench press, agility T-test, and sit-and-reach) showed a significant change across the second half of the program. Consequently, the authors indicated that modifications to training programs should be made to increase the overall effectiveness of PT, specifically after the 8-week period. Thus, it is realistic to assume that if similar or repetitive PT sessions are being implemented twice a week during the ROTC program, then significant improvements may not occur in the PFA components measured late in the semester (i.e., after 8 weeks of PT).

While the fall semester measures revealed significant differences in abdominal circumference between the freshmen and seniors (i.e., freshman had a smaller abdominal circumference than the seniors) and in sit-ups between the freshmen and juniors (i.e., the juniors performed more sit-ups than the freshmen), no significant differences were observed across the spring semester testing sessions. These findings may be a result of the required PT improving the PFA scores and overall fitness of the freshmen to the PFA and fitness levels of their fellow upperclassmen cadets. Recently, Oliver et al. (2017) investigated the effects of PT in freshman U.S. Army ROTC cadets throughout the 9-month academic year. Their results indicated that PT is effective in improving the fitness level of freshman cadets when implementing the Army PFA. Interestingly, the improvements were evident when the PFA was used, while only minor improvements in performance were observed when clinical-based measurements were used. Specifically, no significant changes in body composition, maximal aerobic capacity, or lower-body power were observed. Additionally, while there were significant differences in the cadets' scores from the pretraining to mid-training evaluations, no significant differences occurred between mid-training to post-training evaluations for the male cadets, which is in support of our findings as well as the findings of the aforementioned study by Crawley et al. (2015). However, it is important to note that the U.S. Air Force ROTC cadets who participated in the present investigation scored exceptionally high in each of the PFA components as well as the composite score. Due to these observations, it is possible that our findings showed few improvements as the cadets progressed in the program in addition to few differences between class ranks. Another reason for the small differences may be linked to cadet attrition rates during the program (~30 cadets drop per academic year). While the exact reasons that the cadets dropped the program are not known, some of the cadets may have dropped in part due to an inability to sustain a physical level matching that of their fellow cadets. Consequently, it may be beneficial for the mandatory physical training to be adjusted for cadets who are just entering the program or are less fit to improve their physical performance, increase retention rates, and better prepare them for their future military career.

Similar to the longitudinal assessment, there was an unanticipated absence of differences between class ranks. Only the sit-ups showed significant differences; the freshman class performed significantly fewer sit-ups than the sophomore and junior classes did. Again, this result may be due to the excellent fitness status of the cadets who participated in this investigation. To the best of our knowledge, no other studies in the ROTC cadet population have examined differences between class ranks. In addition, the majority of research studies available at this present time have involved the U.S. Army ROTC population (Thomas et al., 2004; Crombie et al., 2012; Gist et al., 2015; Jones et al., 2012; Liguori et al., 2012; Schiotz et al., 1998; Steed et al., 2016; Crawley et al., 2015). As previously mentioned, the fitness assessments of the U.S. Army (2013) and the U.S. Air Force (2013) differ in the distance, time, and point allocation of the components being evaluated. Thus, only speculations can be made when comparing the two assessments.

Quantifying an individual’s physical fitness can be assessed through a variety of methods, but the methods are commonly characterized as field-based or clinical methods. While the PFA utilized by the U.S. Air Force is meant to measure airmen’s physical condition via cardiovascular endurance (a 1.5-mile run), muscular endurance (1 minute of pushups and 1 minute of sit-ups), and body composition (abdominal circumference); muscular strength and flexibility, which are considered basic components of physical fitness, are not measured (Heyward and Gibson, 2014). The inclusion of muscular strength and flexibility components in the U.S. Air Force PFA may aid in a more comprehensive physical fitness evaluation. In addition, although these field-based assessments allow for time-efficient evaluations of large groups, their ability to provide accurate and discriminate analyses may be limited (Thomas et al., 2004; David, 1995). However, clinical assessments of physical fitness may possess a higher degree of reliability and validity in comparison to field-based measurements (Gibbons et al., 1997). While previous studies by Thomas et al. (2004) and Oliver et al. (2017) implemented both field-based (U.S. Army physical readiness test) and clinical assessments (VO2max, 1-repetition maximum bench press, vertical jump, body fat percentage) in their studies with U.S. Army ROTC cadets, these measures served as more of a physical fitness profile regarding the cadets' status in training than an evaluation of the validity of the field-based assessments. Future research with ROTC cadets or tactical athletes (active duty military members, firefighters, or police officers) may consider incorporating more clinical assessments in addition to field-based assessments to provide a better understanding of the individuals' physical performance characteristics. However, if both types of assessments are implemented, a regression between the measurements examining similar components (e.g., cardiovascular endurance: 1.5-mile run and VO2max) should be conducted to determine the validity of the field-based measurements.

The purpose of this investigation was to provide a longitudinal analysis of the PFA scores of U.S. Air Force ROTC cadets over a four-year period. To our knowledge, no other studies have examined the longitudinal performance of U.S. Air Force ROTC cadets in the PFA or compared their PFA scores between class ranks. There were few differences observed in the present study, which may be due to the fitness status of the participants, a relatively small number of participants, and/or the small amount of mandatory PT (2 hours per week). In addition, although the cadets in this study scored well on the PFA, it is important to note that effort/motivation may have been a potential factor impacting the results. There is a possibility that once cadets reached the maximum score needed for a component, they slowed or stopped their pace, preventing them from completing as many pushups or sit-ups as possible or running as fast as possible. Nonetheless, of the components evaluated in the present study, only the sit-up component may be able to discriminate between the class ranks. These findings suggest that the U.S. Air Force PFA may not be sensitive enough to distinguish physical performance characteristics of high-performing cadets between class ranks in the ROTC population. As a result, the assessment may not be sensitive enough to identify changes across 4 years of physical training.

2.5.5. Conclusions

With the exception of the sit-up component, no changes in physical performance were observed among the ROTC cadets. While the U.S. Air Force ROTC PT may not improve physical fitness (as measured by the current PFA); however, it is important to note that the PT was able to maintain the exceptionally high scores produced by the cadets who were examined in this investigation. Therefore, if the goal is the maintenance of a fitness level, then it appears that the current PT regimen is suitable. However, for cadets who are struggling to meet current PFA standards, it may be beneficial for the PT to be adjusted to improve their physical performance, increase retention rates, and better prepare them physically for their future military career. Incorporating other components of physical fitness (e.g., muscular strength and flexibility) as well as potential lab-based assessments may aid in understanding the current fitness levels of cadets and servicemembers. Implementing a more comprehensive PFA may provide more information to assist physical training leaders in building and facilitating PT regimens. These findings suggest that the current PFA may not be able to detect changes in physical fitness or distinguish between class ranks in terms of physical performance in ROTC cadets.

2.6. **Mackey, C.S.**, Johnson, Q.R., Dawes, J.J., and DeFreitas, J.M. Impact of summer break on physical performance among Air Force Reserve Officers' Training Corps cadets. *Aerospace Medicine and Human Performance*, 2020. (In Review).

2.6.1. Introduction

The Reserve Officers' Training Corps (ROTC) is one of three primary commissioning sources for officers in the United States military. Currently, the Air Force ROTC program is the largest and oldest source of commissioned officers for the U.S. Air Force. Specifically, the Air Force ROTC's program is located on 145 college and university campuses along with more than 1,100 additional institutions across the U.S. A key element of Air Force ROTC programs is to physically prepare cadets for the rigors of military service. Thus, physical training (PT) serves as an important component of the ROTC experience which seeks to improve overall physical fitness, develop discipline and comradery (Thomas et al., 2004). Being physically fit allows cadets and airmen to properly support the Air Force mission, and PT is incorporated as a part of the Air Force culture to establish an environment for members to maintain physical fitness and health to meet expeditionary mission requirements (Department of the Air Force, 2013).

The Air Force uses the directives provided in Air Force Instruction (AFI) 36–2905 to conduct its physical fitness assessment (PFA), consisting of 1-minute push-ups, 1-minute sit-ups, a waist measurement (inches), and a 1.5-mile run component (Department of the Air Force, 2013). The PFA is structured to assess the muscular endurance of specific muscle groups and the functional capacity of the cardiovascular system (Department of the Air Force, 2013). Additionally, the PFA is meant to provide commanders with a tool to assist in the determination of overall fitness of their military personnel and is the primary instrument for evaluating cadet fitness (Department of the Air Force, 2013). For cadets in ROTC programs, the PFA is taken each semester and contracted cadets (i.e., those on scholarship) must pass in order to avoid disciplinary action or dismissal from the program (Department of the Air Force, 2018). Currently, Air Force ROTC cadets are required to take part in PT at least twice per week during the semester and at least 80 percent attendance is mandatory in order to pass their leadership laboratory course (Department of the Air Force, 2018). However, this mandatory PT only takes place during the fall and spring semesters. This means that cadets are without a structured/mandatory PT program over the summer period (~3 months) and could be susceptible to detraining.

Detraining, the partial or complete loss of training-induced adaptations, may have a significant negative impact on aerobic and anaerobic performance (Liguiori et al., 2012; Mujika and 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 if the training stimuli is reduced or completely removed (Mujika and Padilla, 2000). Studies by Mujika and Padilla (2000) reported that maximal oxygen uptake can be reduced between 4-14% in less than 4-weeks, and up to 20% during long-term (greater than 4-weeks) training cessation. In addition, these authors found that endurance performance declines rapidly (less than 4-weeks) as a consequence of an insufficient training stimulus and that significant or complete reversal of training-induced performance improvements occurs during long term inactivity (Mujika and Padilla, 2000). While limited research has been conducted on the fitness levels of ROTC cadets (Liguiori et al., 2012; Thomas et al., 2004), to the authors' knowledge, no published studies have examined changes in PFA performance in Air Force ROTC cadets' following summer break when PT is not mandatory. Consequently, it is unknown to what extent ROTC cadets PFA scores are affected by summer break. Therefore, the purpose of this investigation was to determine if significant changes in cadet physical performance occur after summer break when training is not mandatory. We hypothesized that PFA performance measures would decrease as a function of detraining over summer break.

2.6.2. Methods

Subjects

Male (n = 28) and female (n = 10) Air Force ROTC cadets (mean ± SD; age 20.16 ± 1.31; height 175.63 ± 7.94 cm; body mass 74.9 ± 11.38 kg; body mass index 24.01 ± 2.57) performed the PFA (body composition, 1-minute pushups, 1-minute sit-ups, and 1.5-mile run) in both the spring (April) and fall (August) semesters of 2018. Additionally, cadets were split into two groups depending on participation in field training over the summer [FT; n = 12 (male = 6, female = 6)] or did not [NFT; n = 26 (male = 22, female = 4)] to determine if engagement in field training had any effect on cadet performance in the fall. During the spring semester, cadets had participated in mandatory PT sessions twice per week (one hour per session) from January through April, which generally consisted of a group-organized warm-up, pushups, pull-ups, sit-ups, and running. The University Institutional Review Board for human subject's research approved this study (ED-18-94) and an informed consent was signed by participants prior to data gathering and analysis.

Air Force Physical Fitness Assessment

Officers and noncommissioned officers who were physical training leader certified conducted the field-based tests according to AFI 36-2905 as part of the usual program assessment practices (Department of the Air Force, 2013). Anthropometrics was the first component assessed followed by the timed pushups, sit-ups, and the 1.5-mile (2.4 k) run. A standardized rest period of 3-minutes was utilized between components. Cadets receive up to 60 points for the run, 20 points for the abdominal circumference measurement, and 10 points each for the sit-up and pushup components. The composite score is the sum of each component score out of a possible 100 points. Cadets perform the PFA at least once per semester, must earn a composite score of 75 or greater, and meet the component minimums in order to pass the PFA. A composite score of 74.9 or lower and/or one or more component minimums not met results in an unsatisfactory PFA.

Anthropometrics

Measurements included height, body mass, and abdominal circumference measurements (inches) on a calibrated scale. However, only the abdominal circumference measurement was used for the body composition component score (Department of the Air Force, 2013). For abdominal circumference, the cadets stood stationary while the tester conducted the measurement using a standard tape measure starting at the superior border of the iliac crest and moving around them to place the tape in a horizontal plane around the abdomen. The tester took three measurements to the nearest half inch and the average was recorded for the abdominal circumference score. Males needed a minimum abdominal circumference of 39 inches (12.6 points) and females needed 35.5 inches (12.8 points) in order to pass this component (maximum of 20 points possible).

Pushups

Cadets performed push-ups starting in the “up” position in which hands were slightly wider than shoulder width apart, palms or fists on the floor with arms fully extended while maintaining a rigid hip and spinal posture. On command, the cadet would bend his elbows and lower his entire body as a single unit until the upper arms were at least parallel with the ground (elbows bent at 90 degrees). The cadet returned to the starting position while raising his entire body until the elbows were fully extended. Any deviation to this form resulted in the attempt not being counted toward their component value. Cadets performed continuous push-ups for 1-minute or volitional fatigue and the results were recorded. Males needed a minimum pushup score of 33 (5 points) and females needed 18 (5 points) in order to pass this component (maximum of 10 points possible).

Sit-Ups

Cadets performed sit-ups by starting on their back with the knees bent at a 90-degree angle and their feet or heels in contact with the floor. A partner held the feet with hands, applying adequate pressure across the dorsum of the foot to keep the heels anchored to the floor. The heels were required to remain in contact with the ground throughout the test. With the cadet’s arms crossed over their chest and hands/fingers on the shoulders or resting on the upper chest, the cadet performed a complete repetition when they rose from the down position until the elbows touch the knees or thighs, and then returned to the down position so that the shoulder blades touch the floor/mat. Any deviation to this form resulted in the attempt not being counted. Cadets performed continuous sit-ups for 1-minute and the results were recorded. Males needed a minimum sit-up score of 42 (6 points) and females needed 38 (6 points) in order to pass this component (maximum of 10 points possible).

1.5-Mile (2.4k) Run

The run was performed on an approved distance course. Cadets gathered at a 400-m track and were briefed about the purpose and organization of the test. An officer or noncommissioned officer delivered a standardized set of instructions according to AFI 36-2905 (Department of the Air Force, 2013) then used a stopwatch to record total time as each cadet completed the 1.5-mile (2.4k) run. Males needed a minimum run time of 795-816 seconds (42.3 points) and females needed 951-982 seconds (44.1 points) in order to pass this component (maximum of 60 points possible).

Statistical Analyses

All data was analyzed using PASW software version 24.0 (SPSS Inc, Chicago, IL, USA). Separate two-way mixed factorial ANOVAs [Group (FT vs. NFT) × Time (spring vs. fall) were run for each dependent variable (1-minute pushups, 1-minute sit-ups, abdominal circumference, run time, and composite score). When appropriate, follow up analyses included t-tests with Bonferroni corrections. Partial eta squared (ηp^2) values were reported to estimate ANOVA effect sizes. An alpha level of $p \leq 0.05$ was considered significant for all comparisons.

2.6.3. Results

Abdominal Circumference

A significant time × group interaction was observed for abdominal circumference ($F_{1, 36} = 5.62$; $p = 0.023$, $\eta p^2 = 0.14$). Pairwise comparisons revealed no significant differences between the FT and NFT groups ($p = 0.09$). However, paired samples t-tests indicated that while the FT group did not differ between time points ($p = 0.24$) the NFT did (mean difference = 1.08, $p \leq 0.001$). In addition, there was a main effect for time ($F_{1, 36} = 4.12$; $p = 0.05$, $\eta p^2 = 0.10$) in which cadets had a significantly larger abdominal circumference in the spring (32.04 ± 2.67 inches) compared to the fall (31.33 ± 2.37 inches) semester (Figure 13 E).

Pushups

No time × group interaction was observed for pushups ($F_{1, 36} = 2.58$; $p = 0.12$, $\eta p^2 = 0.07$). However, there was a main effect for time ($F_{1, 36} = 5.70$; $p = 0.022$, $\eta p^2 = 0.14$) in which cadets performed significantly more pushups in the spring (54.26 ± 13.18 repetitions) compared to the fall (50.45 ± 14.77 repetitions) semester (Figure 13 B).

Sit-ups

No time × group interaction was observed for sit-ups ($F_{1, 36} = 1.23$; $p = 0.33$, $\eta p^2 = 0.03$). However, there was a main effect for time ($F_{1, 36} = 5.66$; $p = 0.016$, $\eta p^2 = 0.14$) in which cadets performed significantly more sit-ups in the spring (56.34 ± 6.45 repetitions) compared to the fall (53.24 ± 9.58 repetitions) semester (Figure 13 C).

Run Time

A significant time × group interaction was observed for run time ($F_{1,\,36} = 5.46$; $p = 0.025$, $\eta p^2 = 0.13$). Pairwise comparisons revealed no significant difference between the FT and NFT groups ($p = 0.91$). In addition, paired samples t-tests indicated that both the FT and NFT groups ran the 1.5 mile run significantly faster in the spring compared to the fall semester ($p \leq 0.001$). There was a main effect for time ($F_{1,\,36} = 56.93$; $p \leq 0.001$, $\eta p^2 = 0.61$) in which cadets ran the 1.5 mile run significantly faster in the spring (666.45 ± 76.10 seconds) compared to the fall (713.11 ± 78.53 seconds) semester (Figure 13 D).

Composite Score

No time × group interaction was observed for composite score ($F_{1,\,36} = 3.33$; $p = 0.08$, $\eta p^2 = 0.09$). However, there was a main effect for time ($F_{1,\,36} = 19.43$; $p \leq 0.001$, $\eta p^2 = 0.35$) in which cadets performed significantly better in the spring (mean ± SD; 94.02 ± 5.66) compared to the fall (90.67 ± 5.66) semester (Figure 13 A).

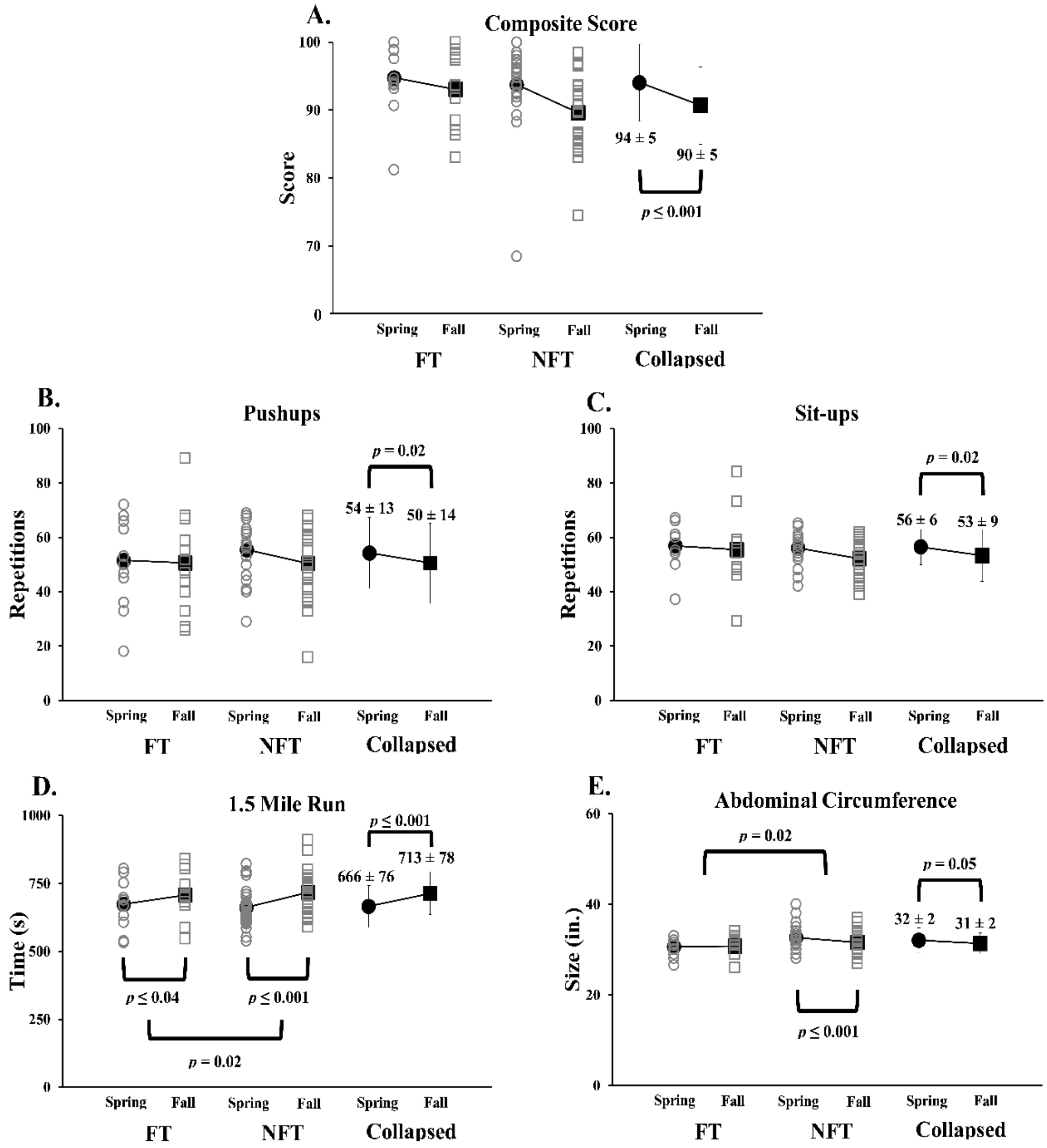

Figure 13. Composite (A), pushup (B), sit-up (C), 1.5 mile run (D), and abdominal circumference (E) physical fitness assessment scores for each cadet who either participated in field training (FT) or did not participate in field training (NFT), including collapsed scores, during the spring (circles) and fall (squares) semesters.

2.6.4. Discussion

The purpose of this investigation was to determine if significant changes occur in cadet physical performance after summer break when training is not mandatory. The primary findings of the present investigation were that significant reductions in performance on the PFA occurred following summer break (i.e., 3 months of unsupervised/non-mandatory physical training). In addition, it appears that even those cadets who participated in field training during the summer break were unable to maintain their scores from the spring semester PFA. Furthermore, our findings revealed that although there were no differences in abdominal circumference between FT and NFT groups, a larger abdominal circumference was recorded in the spring compared to the fall. The results of this study are significant and contribute to the field by providing additional evidence that a break in mandatory physical training negatively impacts muscular endurance, and cardiorespiratory fitness (CRF) in this population. These findings can be used by physical fitness leaders (PFL) to develop self-directed and/or group-organized strength and conditioning programs to maintain physical fitness and reduce the likelihood of detraining between periods of mandatory training.

Several investigations have shown that participation in a structured physical training program, such as those offered by ROTC, has a positive impact on health, fitness, and physical performance within ROTC populations (Liguiori et al., 2012; Mujika and Padilla, 2000; Roy et al., 2010; Thomas et al., 2004). In fact, previous research by Thomas et al. (2004) exemplified the importance of participation in a standard ROTC physical training program for Army cadets. After completing three days per week of physical training that included regular resistance and aerobic training over the course of 28 weeks during the academic year for one hour each day, cadets scored above the 83rd percentile on all Army Physical Fitness Test items. Although our study had a separate methodological design, significant decreases in pushup and sit-up ability were observed over the course of the summer break for a group of cadets that had a similar training background as those in the study by Thomas et al. (2004). While there is a paucity of literature examining the effects of a break in mandatory physical training for a military and/or tactical population (Liguiori et al., 2012), our findings aid in elucidating the effects a summer break has on physical fitness performance in an ROTC population.

Recently, there has been an increase in investigations studying the relationships between abdominal circumference and physical fitness in tactical populations (Griffith et al., 2018; Jones et al., 2012; Nogueira et al., 2016: Steed et al., 2016), but limited information is available regarding changes in abdominal circumference over the course of a break and its effects on physical performance. For example, Nogueira et al. (2016) analyzed the relationship between CRF and waist circumference (WC) in over 4,000 male firefighters and observed that as the firefighter's WC decreased their CRF increased. Similarly, Steed et al. (2016) demonstrated that as percent body fat increased so did the 2-mile run time in Army ROTC cadets. While the findings by Nogueira et al. (2016) and Steed et al. (2016) were able to show the relationship between abdominal circumference and/or body composition with physical fitness, our study may be the first to have explored the effects of detraining on abdominal circumference in ROTC populations. Our investigation revealed a reduction in abdominal circumference in the spring compared to the fall semester (Figure 13 E). This smaller abdominal circumference measurement was unexpected, and may have been due to changes in diet, physical activity level, or hydration status (i.e., water weight). However, due to the decrement in sit-up performance post break, the researchers would posit these changes were most likely the result of a reduction in the amount of time spent training the abdominal muscles over the break.

Timed pushups and sit-ups, or assessments of local muscular endurance, are often utilized to assess physical fitness levels and active-duty readiness in the ROTC population (Department of the Air Force, 2018; Thomas et al., 2004). In our study, cadets performed significantly more pushups and sit-ups in the spring compared to the fall. Specifically, timed pushup performance dropped by ~7% (Figure 13 B), and timed sit-up performance dropped ~5% (Figure 13 C) over the course of the summer break. While a decrease in physical activity level over summer break most likely explains the decrements in performance seen in these measures, a limitation of this study is that actual physical activity was not accounted for over the summer break. The researchers believe that accounting for physical activity, perhaps by surveying cadets, would help bridge the gap on descriptively understanding the difference between in-semester versus summer break physical activity levels. Overall, if the goal is reducing the effects of detraining, the authors encourage PFLs to provide a progressive exercise program focused on improving, or at the least, maintaining local muscular endurance during a non-mandatory physical training period in order to prevent cadets from losing progress towards becoming or staying physical fit for service.

The 1.5-mile run is used in the Air Force PFA as their field test measure of CRF and general health status (Department of the Air Force, 2013). The present study observed significant increases in 1.5-mile run times for cadets in the fall compared to the spring, which may be due to diminished fitness or detraining. While the results of this investigation agree with previous research which indicates that significant decreases in

CRF can occur in less than 4-weeks of training cessation (Liguiori et al., 2012; Mujika and Padilla, 2000; Nogueira et al., 2016), this investigation revealed this occurrence over the course of a three-month break from mandatory physical training. Although cadets may exercise over the course of the summer break, improvements in fitness cannot be maintained or enhanced without a sufficient training stimulus (i.e., appropriate training volume and intensity). As observed in the present study, even cadets who participated in field training over the summer experienced significant reductions in CRF in the fall. Therefore, it is suggested that cadets are given a physical fitness regimen incorporating a sufficient amount training over the break to maintain CRF.

There are a few potential limitations to this study that should be addressed. Although PFA scores were observed at two time points, the spring and the fall, it may be more beneficial to include additional time points (i.e., summer and/or winter PFA). The inclusion of these additional PFA's may aid in bridging the gap between current findings and the postulations in our field of study about changes in PFA performance over the course of a break from mandatory physical fitness programs. Second, after identifying specific changes in PFA performance over the course of a break, investigators could then utilize their findings to compare and quantify the extent of these temporal changes throughout the academic year. By identifying these changes, ROTC programs could identify potential problem time periods and better tailor or implement physical training regimens for their cadets. Additionally, collecting physical activity/training and diet information throughout an academic year may aid in providing supplementary information which could be used to identify outside factors impacting cadet's physical performance. Lastly, assessing changes in PFA performance based on class rank (i.e., freshman, sophomore, junior, senior) would allow for ROTC commanders and cadre to see if more time in the program leads to better physical performance.

2.6.5. Conclusions

This study was designed to determine if significant changes in cadet physical performance occur after summer break when training is not mandatory. The evidence of the present study indicated that non-mandatory physical training over summer break may significantly decrease a cadets' performance on the PFA. In addition, it appears that even the inclusion of field training for some cadets was not enough to prevent the detraining that took place over summer break. Therefore, PFLs should consider implementing a physical training program during non-mandatory training periods in order to help cadets minimize any unnecessary reductions in fitness levels. This may aid in decreasing the amount of re-training that occurs each academic year for ROTC detachments.

CHAPTER III

ONGOING RESEARCH PROJECT

3.1. Purpose of the Study

To examine the physical fitness profile of ROTC cadets and U.S. military veterans. A secondary aim of this investigation was to compare civilian, ROTC cadet, and U.S. military veteran populations' physical fitness evaluation scores.

3.2. Research Questions

This study has the potential to provide new information regarding the current physical fitness profile of ROTC cadets and U.S. military veterans. The following research questions are those that have the potential to be answered by the present study and that have not been answered in the literature.

- How do physical fitness evaluation scores for ROTC cadets compare to current norms? And, how do their scores compare to an average civilian and U.S. military veteran populations?

- How do physical fitness evaluation scores for young U.S. military veterans compare to current norms? And, how do their scores compare to an average civilian and ROTC cadets?

3.3. Hypotheses (current norms and scores based upon ACSM's percentile rankings)

- ROTC cadets will have higher physical fitness evaluation scores than the current norms, civilian, and U.S. veteran scores.
- U.S. military veterans will meet or have lower scores than the current norms and the civilian group.

3.4. Limitations

- Participants will be gathered through convenience sampling, therefore, the process of subject selection may not truly be random.
- Due to location, ROTC cadets will be limited to Army and Air Force branches.
- Participants will be males and females between 18-45 years of age.
- A handheld goniometer will be used for flexibility/range of motion assessments.

3.5. Assumptions

- The samples will be normally distributed and representative of their respective populations.
- Participants' responses to the health history questionnaire will be accurate and valid.
- No ergogenic supplementation will be used within twelve hours of testing.
- All participants will give a maximal effort during all testing and training sessions.
- Equipment will function properly for testing.

- That there will no be data collection, data analyses, data entry, nor statistical processing errors.

3.6. Methods

Participants

Using convenience sampling, participants were recruited via email, classrooms with a verbal script, hanging flyers, and word of mouth. Participants were placed into three separate groups based on their current status: 1) Civilian (mean ± SD; age 26.4 ± 5.0; height 174.3 ± 8.5 cm; body mass 83.7 ± 14.5 kg); 2) ROTC cadet (age 19.5 ± 1.6; height 175.6 ± 6.4 cm; body mass 74.2 ± 7.5 kg); 3) Veteran (age 33.0 ± 7.5; height 181.7 ± 8.0 cm; body mass 98.5 ± 10.8 kg). Participants placed into the civilian group were those who are not and have not served in the armed forces (Army, Navy, Air Force, Marines, and Coast Guard), the ROTC cadet group were those who are actively enrolled and part of the university ROTC program, and the veteran group were participants who are former members of the armed forces that served on active duty and received a discharge other than dishonorable. For the purpose of this study, only veterans who were discharged within the past ten years were included to keep the age difference of the participants within reason. Participants who report any musculoskeletal injuries of the upper and/or lower extremities within 12 months before testing will be excluded. This study was approved by the University Institutional Review Board for human subject's research (ED-19-104), and before any testing; each participant completed an informed consent document and health history questionnaire.

Research Design

This study used a cross-sectional design to investigate differences between the three groups previously mentioned. Through the use of quantitative and semi-quantitative measures, the information acquired provided data addressing individuals as well as group information throughout the study. The dependent variables being measured are body composition (body mass index; BMI and body fat percentage; %), flexibility (sit-and-reach test; cm) and goniometry of the shoulder (flexion), hip (flexion and extension), and knee (flexion), muscular strength (1-RM bench press and leg press), muscular endurance (1 minute push-up and sit-up tests), and cardiorespiratory fitness (VO_{2max}).

Procedures

Participants visited the laboratory 1-2 times depending on their time availability and familiarity with the assessments. Following completion of the informed consent during their first visit, participants had their body composition and flexibility assessments administered along with being familiarized on the assessments described in the following section. Within 2-4 days following their first visit (should participants require a second visit), participants were asked to return to the laboratory to complete the physical fitness assessment. Following body composition measurements and prior to fitness testing, participants performed a five minute warm-up on a cycle ergometer (Monark Exercise 828E, Vansbro, Sweden) at a self-selected low-intensity (50-60 rpm) workload.

Body Composition

After consent, height (cm) and weight (kg) were measured with the participant wearing loose fitting gym clothes (i.e. t-shirts, athletic shorts, etc.) with shoes removed.

BMI was calculated as kg/m^2. After height and weight were recorded, participants skeletal muscle mass, fat mass, and percent body fat were measured using multi-channel bioelectric impedance (InBody 270 Body Composition Analyzer: InBody USA). All participants fasted the night before the measurements being taken. Further, participants were wearing sports shorts and T-shirt, were barefoot, and had all metal, plastic, and magnetic accessories removed, stood on the device and on the metal spots designated for their hands and feet.

Flexibility

Participants were in a seated position without shoes and the soles of the feet flat against the sit-and-reach box (flexometer) at the 26 cm mark. Once situated, the participants slowly reached forward with both hands as far as possible, holding this position for 2 seconds. The primary investigator ensured that the participant kept their hands parallel and does not lead with one hand while also keeping their knees extended. Fingertips were allowed to overlap while remaining in contact with the measuring portion of the sit-and-reach box. Two trials were recorded and the most distant point reached with the fingertips was taken for analysis (ACSM's Guidelines for Exercise Testing 2018, p. 102-104).

Goniometry measurements were utilized to determine active range of motion during shoulder flexion, hip flexion and extension, and knee flexion, following the guidelines of Clarkson et al. (2000) and Palmer & Epler (1998). Two trials were measured for each assessment with the best range of motion (degrees) measurement being used for analysis. For shoulder flexion, participants were lying in a supine position, in which the goniometer axis of rotation was placed at the acromion process with the stationary in line with the thorax and the moving arm at the midline of the humerus (lateral epicondyle). Participants were then instructed to keep their arm straight/rigid while flexing their dominant arm in the sagittal plane and holding the furthest position until measurement is completed. For hip flexion, participants were lying in a supine position, the goniometers axis of rotation will be placed at the center of the greater trochanter with the stationary arm in line with the thorax and the movement arm at the lateral midline of the femur using the lateral epicondyle for reference. Participants were then instructed to slowly flex their dominant leg holding the furthest position until the measurement is completed. Hip extension was assessed similar to hip flexion with the exception that participants laying in a prone position. For knee flexion, participants were laying in a supine position, the goniometers axis of rotation over the lateral epicondyle of the femur with the stationary arm in line with the femur using the greater trochanter for reference and the moving arm in line with the fibula using the lateral malleolus for reference.

Muscular Strength

Muscular strength testing comprised of a 1-RM bench press and leg press. For both exercises participants followed the National Strength and Conditioning Association's (NSCA) 1-RM testing protocol (Haff & Triplett, 2016, p. 453) detailed below. Each lift followed the instructions set by the NSCA (Haff & Triplett, 2016, p. 371 & 379) for a satisfactory/successful repetition.

1. Participant instructed to warm up with a light resistance that easily allows 5 to 10 repetitions.

2. 1-minute rest.
3. Estimated a warm up load that will allow the participant to complete 3 to 5 repetitions by adding:
    a. 10 to 20 pounds (4-9 kg) or 5-10% for bench press.
    b. 30 to 40 pounds (14-18 kg) or 10-20% for leg press.
4. 2-minute rest.
5. Estimated a near maximal load that will allow the participant to complete 2 to 3 repetitions by adding:
    a. 10 to 20 pounds (4-9 kg) or 5-10% for bench press.
    b. 30 to 40 pounds (14-18 kg) or 10-20% for leg press.
6. 2- to 4-minute rest.
7. Increase load for participant by adding:
    a. 10 to 20 pounds (4-9 kg) or 5-10% for bench press.
    b. 30 to 40 pounds (14-18 kg) or 10-20% for leg press.
8. 1-RM attempted by participant.
9. If successful, another 2- to 4-minute rest period will be provided and repeat step 7. If unsuccessful, a 2- to 4-minute rest period will be provided, then decrease the load by subtracting:
    a. 5 to 10 pounds (4-9 kg) or 5-10% for bench press.
    b. 15 to 20 pounds (14-18 kg) or 10-20% for leg press.
    c. Go back to step 8.
10. Continue until participant’s 1-RM is completed. 1-RM will be found within 5 attempts.

Muscular Endurance

Following a 5-minute rest period from the last muscular strength assessment, participants were administered a 1-minute sit-up (crunch) test, a 5-minute rest period, and then a 1-minute push-up test. Instructions for each of the muscular endurance assessments are outlined in American College of Sports Medicines Guidelines for Exercise Testing and Prescription (8th-10th Ed., p. 93-94 & 101-102), but will be described here. For the sit-up test, participants assumed a supine position on a mat with their knees at 90 degrees. The arms and hands were held across the chest. The participants performed controlled sit-ups to lift the shoulder blades off the mat so that the trunk made an approximate 30 degree angle with the mat. Participants performed as many sit-ups as possible without pausing. The push-up test was administered with participants starting in the down position (hands pointing forward and under the shoulder, back straight, head up, using the toes as the pivotal point). Participants raised their body by straightening the elbows and returning to the down position while maintaining a straight back for a successful repetition. The maximal number of push-up performed consecutively without rest was counted as the score.

Cardiorespiratory Fitness

Following a 10-minute rest period from the last muscular endurance assessment, participants were administered a graded exercise test on a treadmill to volitional exhaustion in order to determine their maximal oxygen uptake/aerobic capacity (VO_{2max}; mL/kg/min). The test was completed on a Trackmaster treadmill (TMX 425C, Newton, KS, USA) with a COSMED Quark RMR metabolic testing system and software using cardio pulmonary exercise testing breath-by-breath analysis. The metabolic cart was calibrated before each test. The highest values recorded during the last 30 seconds of the test were used for analysis. The test began with each participant walking at 6.44 $km \cdot h^{-1}$ (4 mph) and 0% grade. The velocity was increased by 1.61 $km \cdot h^{-1}$ (1 mph) every two minutes to 14.49 $km \cdot h^{-1}$ (9 mph). At 14.49 $km \cdot h^{-1}$, the exercise intensity was then increased by raising the treadmill grade 2% every two minutes until volitional exhaustion (Malek et al., 2005; Bergstrom et al., 2015).

Statistical Analysis

Separate one-way between groups ANOVAs were performed for each dependent variable from the physical fitness assessment with Bonferroni post hoc analyses. PASW software version 24.0 (SPSS Inc, Chicago, IL, USA) was used for all statistical analyses. An alpha level of $p \leq 0.05$ was considered significant for all comparisons.

3.7. Preliminary Findings

Body Composition

The BMI classification for each group is as follows: civilian (27.5 ± 4.1) overweight; ROTC (24.1 ± 2.2) normal; veteran (29.9 ± 4.7) overweight. There was a significant difference between groups for BMI ($F_{2, 29} = 8.04$, p = 0.002). The post hoc analysis revealed that the ROTC cadets had a significantly lower BMI when compared to the civilian group (mean difference = 3.47; p = 0.05) and veteran group (mean difference = 5.88; p = 0.003).

The body fat percentage classification for each group is as follows: civilian (26.7 ± 12.0) very poor (10th percentile); ROTC (15.2 ± 5.8) good (55th percentile); veteran (29.1 ± 8.5) very poor (5th percentile). There was a significant difference between groups for body fat percentage ($F_{2, 29} = 8.93$, p = 0.001). The post hoc analysis revealed that the ROTC cadets had a significantly lower body fat percentage when compared to the civilian group (mean difference = 11.5; p = 0.007) and veteran group (mean difference = 13.9; p = 0.005).

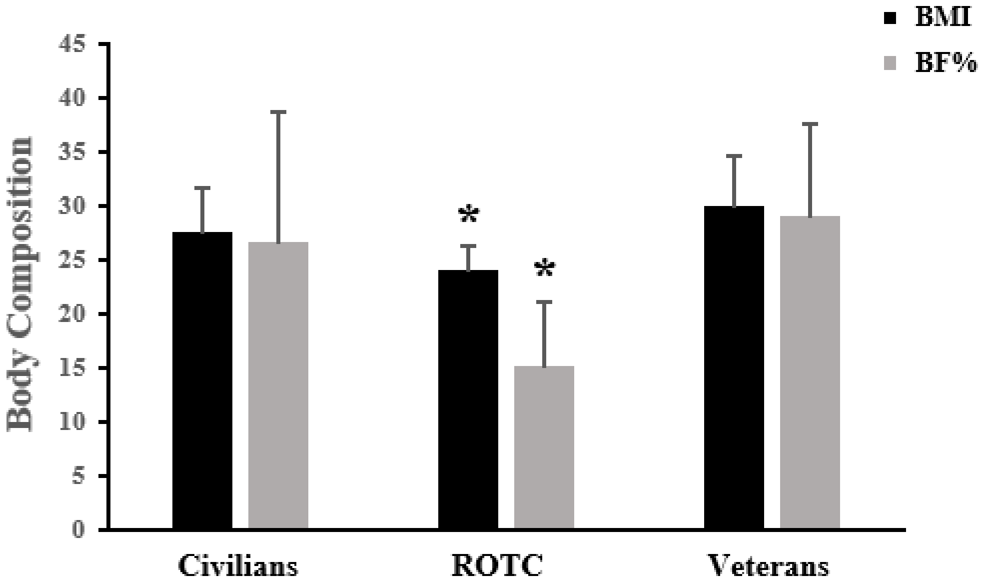

Figure 14. Body composition assessment (Body Mass Index, BMI; Body Fat Percentage, BF%) of civilians, ROTC cadets, and veterans. The black bars represent BMI while the gray bars represent BF%. * Significantly different from civilians and veterans ($p \leq 0.05$).

Flexibility

The sit and reach (cm) flexibility classification for each group is as follows: civilian (25.2 ± 6.3) fair; ROTC (22.1 ± 8.2) poor; veteran (20.1 ± 10.9) poor. No significant differences between groups was observed for the sit and reach assessment ($F_{2, 29} = 0.745$, $p = 0.48$), should flexion ($F_{2, 29} = 2.36$, $p = 0.11$), hip flexion ($F_{2, 29} = 2.07$, $p = 0.15$), hip extension ($F_{2, 29} = 1.99$, $p = 0.15$), nor knee flexion ($F_{2, 29} = 2.44$, $p = 0.11$).

Muscular Strength

The upper body strength classification for each group is as follows: civilian (0.97 ± 0.36) poor (35th percentile); ROTC (1.14 ± 0.31) good (60th percentile); veteran (0.88 ±

0.26) fair (40th percentile). No significant difference between groups was observed for relative upper body strength ($F_{2, 29} = 1.78$, $p = 0.19$) nor absolute upper body strength ($F_{2, 29} = 0.148$, $p = 0.86$).

The lower body strength classification for each group is as follows: civilian (2.00 ± 0.62) average (60th percentile); ROTC (2.35 ± 0.48) well above average (90th percentile); veteran (1.52 ± 0.46) well below average (20th percentile). There was a significant difference between groups observed for relative leg press ($F_{2, 29} = 5.72$, $p = 0.008$). The post hoc analysis revealed that the ROTC cadets had significantly higher relative lower body strength than veterans (mean difference = 0.82; $p = 0.007$). No significant difference was observed between groups for absolute lower body strength ($F_{2, 29} = 1.33$, $p = 0.28$).

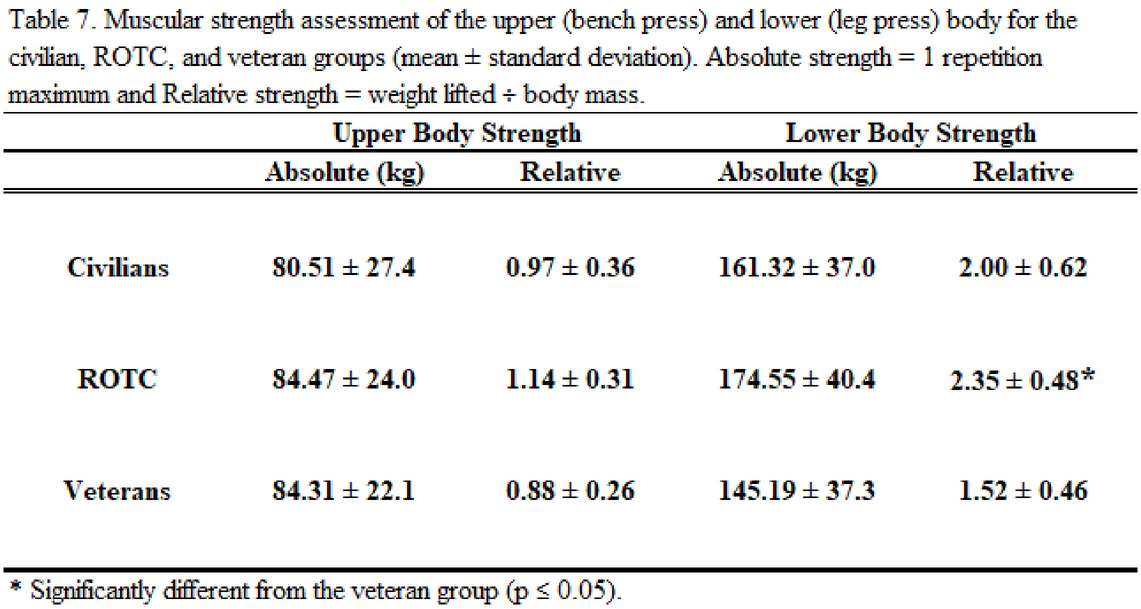

Table 7. Muscular strength assessment of the upper (bench press) and lower (leg press) body for the civilian, ROTC, and veteran groups (mean ± standard deviation). Absolute strength = 1 repetition maximum and Relative strength = weight lifted ÷ body mass.

	Upper Body Strength		**Lower Body Strength**	
	Absolute (kg)	**Relative**	**Absolute (kg)**	**Relative**
Civilians	**80.51 ± 27.4**	**0.97 ± 0.36**	**161.32 ± 37.0**	**2.00 ± 0.62**
ROTC	**84.47 ± 24.0**	**1.14 ± 0.31**	**174.55 ± 40.4**	**2.35 ± 0.48***
Veterans	**84.31 ± 22.1**	**0.88 ± 0.26**	**145.19 ± 37.3**	**1.52 ± 0.46**

* Significantly different from the veteran group ($p \leq 0.05$).

Muscular Endurance

The push-up classification for each group is as follows: civilian (27.7 ± 15.4) good; ROTC (43.2 ± 12.4) excellent; veteran (28.7 ± 11.3) good. There was a significant difference between groups observed for push-ups ($F_{2, 29} = 5.30$, $p = 0.011$). The post hoc analysis revealed that the ROTC cadets had significantly more push-up repetitions than civilians (mean difference = 15.5; $p = 0.023$).

The sit-up classification for each group is as follows: civilian (30.1 ± 10.3) excellent; ROTC (54.5 ± 8.7) excellent; veteran (38.8 ± 15.9) excellent. There was a significant difference between groups observed for sit-ups ($F_{2, 29} = 16.46$, $p \leq 0.001$). The post hoc analysis revealed that the ROTC cadets had significantly more sit-up repetitions than civilians (mean difference = 24.4; $p \leq 0.001$) and veterans (mean difference = 15.7; $p = 0.013$).

Cardiorespiratory Fitness

The VO_{2max} (mL/kg/min) classification for each group is as follows: civilian (40.3 ± 5.2) poor (25th percentile); ROTC (47.1 ± 8.1) fair (50th percentile); veteran (38.5 ± 10.4) poor (35th percentile). There was a significant difference between groups observed for VO_{2max} ($F_{2, 29} = 3.67$, $p = 0.038$). However, the post hoc analysis revealed no statistically significant differences between the civilians, ROTC cadets, and veterans ($p = 0.089\text{-}0.141$). There was a significant difference between groups observed for time to task failure (TTF; s) ($F_{2, 29} = 6.10$, $p = 0.006$). The post hoc analysis revealed that the ROTC cadets ran for a significantly longer period of time when compared to the civilians (mean difference = 209.1; $p = 0.032$) and veterans (mean difference = 257.1; $p = 0.021$).

Table 8. Cardiorespiratory fitness assessment for the civilian, ROTC, and veteran groups (mean ± standard deviation).

	VO2max (mL/kg/min)	**Time to Task Failure (s)**	**Rating of Perceived Exertion**	**Heart Rate**
Civilians	**40.3 ± 5.2**	**605.2 ± 183.8**	**18.6 ± 0.7**	**196.3 ± 8.5**
ROTC	**47.1 ± 8.1**	**814.9 ± 195.9***	**19.1 ± 0.9**	**191.4 ± 12.6**
Veterans	**38.5 ± 10.4**	**557.8 ± 158.7**	**18.0 ± 0.9**	**189.7 ± 9.3**

* Significantly different from the civilian and veteran groups ($p \leq 0.05$).

CHAPTER IV

DISCUSSION

4.1. General Discussion

The primary objective of this document was to investigate the influence of training status on human performance and physical characteristics among civilian and ROTC populations. This chapter will present an integrated discussion briefly outlining the major findings of the previous studies described followed by the preliminary results observed from the ongoing research project. The discussion will conclude with a section that recommends the future direction of research in the military human performance area.

Study 1 (2.1) was designed to determine if maximal and rapid force characteristics as well as fatigue responses of the knee extensors and flexors could discriminate between two different types of training (traditional vs. explosive) among men. The evidence from that investigation seems to support the idea that resistance-trained individuals may react similarly when put through a fatiguing bout of dynamic isokinetic exercise. However, it has been shown that the adaptations to training may be specific to the modality of the training. Therefore, it is possible that training specificity of the two groups led to adaptations that may not completely transfer to isokinetic and isometric performance assessments since they are different modalities. Nonetheless, the study indicated a significant difference for the knee extensors, where RTD_{0-50} was significantly higher for the explosive group compared to the traditional trained group. However, the greater RTD_{0-50} in the explosive trained group was not accompanied by a significantly greater acceleration or maximal velocity. These findings demonstrate that measures of rapid force development may be more sensitive to training-specific adaptations than kinematic variables such as peak acceleration and velocity.

Study 2 (2.2) examined the effects of a power-endurance versus a controlled hypertrophic free-weight back squat exercise on the acute post-exercise recovery responses of maximal velocity and acceleration characteristics of the knee extensors among men and women. This study revealed that both acceleration (~14%) and maximal velocity (~6%) may be negatively affected following moderate to heavy exercise for up to 30 minutes post-exercise. Therefore, the inclusion of assessing these characteristics may be a valuable measure in identifying residual consequences of fatigue and strength and conditioning professionals may use caution when designing lower-extremity exercises, as velocity characteristics may be diminished for an acute period of time (0-30 minutes) following a single exercise bout. However, due to the maximal and rapid velocity capabilities between genders responding similarly following fatiguing bouts of exercise, it is unclear as to whether those measures are sensitive enough measures to reveal gender differences.

Study 3 (2.3) examined the immediate (within exercise bout) and acute (recovery) performance responses after performing two different (controlled heavy vs. power-endurance) free-weight back squat exercise protocols on vertical jump performance in women. While study 2 was able to show deficits in performance following an entire exercise bout, the primary finding of study 3 was the immediate (after one set of squats) decrease in power (~8%), velocity (~7%), and jump height (~10%) along with these variables being further decreased following the entire exercise bout by ~13%, ~12%, and ~14%, respectively. Similar to study 2, the performance variables measured for study 3 (power, velocity, jump height) were decreased for up to 20 minutes post-exercise. Taken together, study 2 and 3 revealed that both isokinetic and dynamic/functional movements can be utilized in order to assess acute fatigue of power and velocity characteristics of the lower extremity following back-squat protocols.

Study 4 (2.4) sought to determine if fatiguing, moderate-velocity muscle actions affect isokinetic (dynamic) strength characteristics to a greater extent compared to their isometric (static) strength counter parts. The primary finding of that investigation was the differential acute responses between isometric (18.71%) and dynamic/isokinetic (45.08%) peak torque fatigue indices. Additionally, the ability to generate strength and velocity rapidly (i.e., rate of torque development and acceleration) had significantly different responses to fatigue between isometric and dynamic assessments. The deficit observed for isometric rate of torque development (~55%) was more than double that seen with the dynamic maximal acceleration (~26%). This demonstration could indicate that the differences in sensitivity of the two types of contractions is a major factor accounting for the loss of force and power during exercise. Consequently, it is important that studies utilizing a fatiguing intervention include testing in the same modality as the fatiguing protocol. Knowing that a number of investigators implement various fatigue modalities, the present findings suggest that pre- and post-isometric and dynamic assessments may vary greatly depending on the type of contractions used during the fatiguing protocol.

Study 5 (2.5) is when the research began incorporating military affiliated personnel into the human performance investigations and examined U.S. Air Force ROTC cadets over a four-year period for the evaluation of potential differences between class rank within the ROTC utilizing the current physical fitness assessment and for the evaluation of the sensitivity of the classification of the tests in terms of absolute test results and composite scores. The primary finding of that investigation was a lack of improvement in most of the variables measured during the longitudinal assessment and the absence of differences between class ranks, with exception of sit-ups (freshman performed fewer sit-ups than the sophomore and junior classes). Although the cadets in this study scored well on the assessment, it is important to note that effort/motivation may have been a potential factor impacting the results. There is a possibility that once cadets reached the maximum score needed for a component, they slowed or stopped their pace, preventing them from completing as many pushups or sit-ups as possible or running as fast as possible. Nonetheless, these observations brought into question whether the U.S. Air Force fitness assessment is sensitive enough to identify physical training-induced changes or the effectiveness of the current physical training regimen (i.e., only training toward the testing standards) even after four years of training.

Study 6 (2.6) was designed to determine if significant changes in cadet physical performance occur after summer break when training is not mandatory. Currently, Air Force ROTC cadets are required to take part in physical training at least twice per week during the semester, and at least 80 percent attendance is mandatory in order to pass their leadership laboratory course. However, this mandatory physical training only takes place during the fall and spring semesters. This means that cadets are without a structured/mandatory physical training program over the summer period (~3 months) and could be susceptible to detraining. The primary findings of this investigation were that significant reductions in performance (push-ups 7%; sit-ups 5.5%; run time 7%; composite score 3.5%) on the fitness assessment occurred following summer break. In addition, it appears that even those cadets who participated in field training during the summer break were unable to maintain their scores from the spring semester fitness assessment. Due to the paucity of ROTC literature currently available, studies 5 and 6 were designed to provide an updated physical performance profile on cadets in regard to their physical fitness assessment they are required to take each semester. While these fitness tests are meant to measure physical conditioning through cardiorespiratory fitness, muscular endurance, and body composition; muscular strength and flexibility, which are considered basic components of physical fitness, are not measured and lead into the ongoing research project.

Study 7 (chapter 3) is designed to examine the physical fitness profile of ROTC cadets and U.S. military veterans. A secondary aim of this investigation is to compare civilian, ROTC cadet, and U.S. military veteran populations' physical fitness evaluation scores. While this study is still in progress, the preliminary findings of the fitness evaluations are as previously hypothesized. The ROTC group ranks in the top 50th percentile for body fat percentage (55th), upper body strength (60th), lower body strength (90th), and cardiovascular fitness (50th). The ROTC VO_{2max} (47.1 ± 8.1 mL/kg/min), upper body strength (bench press 1-RM, 84.47 ± 24.0 kg), and body fat percentage findings (15.2 ± 5.8) are comparable to what Thomas et al. (2004) had previously reported, 49.6 ± 6.1 mL/kg/min, 86.5 ± 24.9 kg, 14.8 ± 4.2, respectively. Additionally, the cadets placed in the normal category for body mass index and the excellent category for both muscular endurance assessments (push-ups and sit-ups). However, for the flexibility assessment, the cadets did fall into the poor category. When compared to the civilian and veteran groups, the ROTC cadets had a significantly healthier body composition (civilians and veterans), higher relative lower body strength (veterans), performed more push-ups (civilians) and sit-ups (civilians and veterans). While the initial analysis of the VO_{2max} assessment showed there was a difference between groups, the post hoc analysis did not reveal any significant differences. This may be due to the low sample size utilized for the preliminary analysis. In order to determine potential differences between groups, time to task failure was utilized and showed that the ROTC group ran for a significantly longer period of time (~3-4 minutes) than both the civilian and veteran groups. Taken together, the ROTC cadets are more physically fit when compared to the civilians and veterans who have participated in this study. However, this does not come as a surprise due to the cadets being younger and engaging in weekly mandatory physical training.

Conversely, the veterans ranked in the lower percentiles for body fat percentage (5th), upper body strength (40th), lower body strength (20th), and cardiovascular fitness (35th). The veteran group had various categorical rankings for the other assessments; body mass index (overweight), flexibility (poor), push-ups (good), sit-ups (excellent). Due to paucity of literature of objective, quantifiable literature on younger veterans, limited comparisons can be made at this time. However, based on how the veteran group ranked on the physical fitness evaluation, these findings do seem to follow the observations made by Koepsell et al. (2012), Littman et al. (2013), and Rosenberger et al. (2011) in which veterans gain weight and engage in less physical activity following their military separation. As hypothesized, the veterans were as physically fit or worse than their civilian counterpart. While no significant differences were found between the veteran and civilian groups, the civilians did rank higher in the following assessments: body fat percentage (10th percentile), flexibility (fair), and lower body strength (60th percentile). At the moment, these findings agree with Littman et al. (2009 and 2013) in which those authors found no significant differences between amount of physical activity between civilians and veterans. Once the study has been successfully completed, the future results may be able to provide additional information on the physical profile of veterans and how they compare to the American College of Sports Medicine's normative values and civilian group.

4.2. Conclusion

The objective of this dissertation was to study the influence of training status on human performance and physical characteristics among civilian and ROTC populations through conducting research studies involving varying populations, sexes, interventions, assessments, and variables measured. This dissertation has illustrated the maximal strength and rapid force characteristics of the upper and lower extremities among men and women along with individuals of differing training backgrounds, and has shown that while specific adaptations may be made depending on how individuals physically train, the appropriate modality of assessment is required in order to ascertain those differences. In addition, it appears that both isokinetic and dynamic/functional movements may be utilized in order to assess acute fatigue responses following lower extremity exercise bouts in men and women. This dissertation has also provided an updated demographic information and physical fitness profile of ROTC cadets. The ongoing research project will attempt to provide additional information regarding physical fitness of not only ROTC cadets, but recently separated military veterans – who are a vastly under-researched population at this time.

From the results of this dissertation, some lines of future research can be identified to further the studies presented. At this time, our knowledge and understanding of military populations (ROTC, active duty, veterans) in terms of physical fitness, capabilities, and characteristics are limited, especially in terms of how these populations compare to their civilian and athletic counterparts. Following the completion of the ongoing research project, future research with military personnel may consider incorporating more laboratory assessments (e.g., isokinetic dynamometry, electromyography, musculoskeletal ultrasonography, etc.) in addition to field-based assessments (e.g., push-ups, sit-ups, upper/lower exercises, etc.) to provide a better understanding of the individuals' physical performance characteristics. Examining and comparing the overall physical fitness of veterans to civilians, ROTC cadets, and active duty military members may help shed more light on the differences between these populations and the toll military service takes on the human body. Also, recently there have been changes to some of the military branch specific physical fitness assessments. Specifically, the U.S. Army has updated their assessment which will have six components that include the dead lift, standing power throw, hand-release push-up, sprint-drag-carry, leg tuck, and 2-mile run. This will inevitably result in changes to how the current soldiers engage in their mandatory physical training each week. Consequently, new training adaptations may arise over time for these soldiers compared to previous generations who trained for and were assessed on the old Army physical fitness test (2-minute push-ups, 2-minute sit-up, and 2-mile run). Future research could seek to acquire updated fitness profiles and evaluations of these soldiers and compare their levels of fitness to the other branches of military along with comparing them to potential previous data profiles on soldiers who were assessed utilizing the preceding version of the fitness test.

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APPENDICES

A. DEFINITION OF TERMS

Acceleration (ACC): also referred to as rate of velocity development. Rate of change in velocity.

Active duty (Servicemember): full-time duty in the uniformed services/armed forces.

Body composition: the relative amounts of muscle, fat, bone, and other vital parts of the body.

Cardiorespiratory endurance: the ability of the circulatory and respiratory system to supply oxygen during sustained physical activity.

Cardiorespiratory fitness: the ability to perform large muscle, dynamic, moderate-to-vigorous intensity exercise for prolonged periods of time.

Civilian: a person not in/belonging to the armed services or police force.

Concentric Muscle Action: a muscle action in which the muscle shortens because the contractile force is greater than the resistive force.

Detraining: the partial or complete loss of training-induced adaptations, and may have a significant negative impact on aerobic and anaerobic performance.

Exercise: a type of physical activity consisting of planned, structured, and repetitive bodily movement done to improve and/or maintain one or more components of physical fitness.

Fatigue: any reduction in physical or mental performance, or any exercise-induced decrease in maximal voluntary force or power produced by a muscle or muscle group.

Fatigue Index (FI): also referred to as percent decline. Used for measuring ability to resist fatigue using this equation [(Post – Pre)/Pre x 100].

Flexibility: the ability to move a joint through its complete range of motion.

Hypertrophy: muscle enlargement resulting from training, primarily owing to an increase in the cross-sectional area of the existing fibers.

Isokinetic Strength Testing: maximal tension is developed at all joint angles throughout the range of motion. Speed, or Velocity, is constant because there is accommodating resistance at a controlled speed of movement.

Isometric Muscle Action: a muscle action in which the muscle length does not change because the contractile force is equal to the resistive force.

Maximal oxygen uptake (VO_{2max}): refers to the maximum amount of oxygen that an individual can utilize during intense or maximal exercise.

Maximal Voluntary Contraction (MVC): participant attempts to concentrically contract as hard as possible with the limb in a fixed position.

Muscular endurance: the ability of a muscle group to execute repeated muscle actions over a period of time sufficient to cause muscular fatigue.

Muscular strength: the ability of muscle to exert maximal force on one occasion.

Physical activity: any bodily movement produced by the contraction of skeletal muscles that results in substantial increase in caloric requirements over resting energy expenditure.

Physical fitness: the ability to carry out daily tasks with vigor and alertness, without undue fatigue, and with ample energy to enjoy leisure-time pursuits and meet unforeseen emergencies.

Power Training: lifting light-to-moderate loads at high velocities.

Reserve Officer Training Corps (ROTC): a college program offered at colleges and universities nationwide that prepares young adults to become officers in the U.S. military.

Specificity Principle: also referred to as the specific adaptation to imposed demands (SAID) principle. This states that the training is most effective when the resistance exercises are similar to the sport or activity in which improvement is sought.

Strength: the maximal force that a muscle or muscle group can generate at a specified velocity.

Strength Training: heavy resistance training with slow velocities.

Torque: application of force to an object on an axis.

U.S. Veteran: a person who served in the active military, naval, or air service and who was discharged or released under conditions other than dishonorable.

Velocity: the rate of motion in a specific direction.

B. REVIEW OF LITERATURE

Aagaard et al., 2000.

The aim of this study was to quantify the amount of antagonist coactivation and the resultant moment of force generated by the hamstring muscles during maximal quadriceps contraction while performing slow isokinetic knee extension. The net joint moment at the knee joint and electromyography (EMG) signals were measured from the following muscles (vastus medialis, vastus lateralis, rectus femoris muscles and the biceps femoris caput longum and semitendinosus) in male subjects during maximal isokinetic knee extension. Two types of extension were performed: (1) maximal concentric quadriceps contractions and (2) maximal eccentric hamstring contractions. Hamstring antagonist EMG in (1) were converted into antagonist moment based on the EMG-moment relationships determined in (2) and vice versa. Antagonist muscle coactivation was present in both (1) and (2). Substantial hamstring coactivation was observed during quadriceps agonist contraction. This resulted in a constant level of antagonist hamstring moment of about 30 N·m throughout the range of motion. The authors concluded that substantial antagonist coactivation of the hamstring muscles may be present during slow isokinetic knee extension. Additionally, substantial antagonist flexor moments are generated. The antagonist hamstring moments potentially counteract the anterior tibial shear and excessive internal tibial rotation induced by the contractile forces of the quadriceps near full knee extension. In doing so the hamstring coactivation is suggested to assist the mechanical and neurosensory functions of the anterior cruciate ligament.

Abernethy et al., 1994.

Skeletal muscle tissue is sensitive to the acute and chronic stresses associated with resistance training. These responses are influenced by the structure of resistance activity (i.e. frequency, load and recovery) as well as the training history of the individuals involved. Increases in cross-sectional area of muscle after resistance training can be primarily attributed to fiber hypertrophy. However, there may be an upper limit to this hypertrophy. Furthermore, significant fiber hypertrophy appears to follow the sequence of fast twitch fiber hypertrophy preceding slow twitch fiber hypertrophy. The purpose of this article was to summarize some of the skeletal muscle responses to acute and chronic resistance activity.

Beck et al., 2005.

The primary purpose of this study was to compare the fast Fourier transform with the discrete wavelet transform for determining the mechanomyographic and electromyographic center frequency (mean power frequency, median frequency, or wavelet center frequency) patterns during fatiguing isokinetic muscle actions of the biceps brachii. Subjects volunteered to perform 50 consecutive maximal, concentric isokinetic muscle actions of the dominant forearm flexors at a velocity of 180° s^{-1}

through a 90° range of motion using a neutral handgrip. This study was included primarily because of the authors fatigue protocol and isokinetic testing setup.

Beck et al., 2012.

The purpose of this study was to examine the strength, EMG, and mechanomyographic (MMG) responses after workouts designed to elicit fatigue and muscle damage vs. only fatigue. Subjects performed 6 sets of 10 maximal concentric isokinetic or eccentric isokinetic muscle actions of the dominant forearm flexors on 2 separate days. Before (Pre) and after (Post) these workouts, peak torque, surface EMG, and MMG signals were measured during maximal concentric isokinetic, eccentric isokinetic, and isometric muscle actions of the forearm flexors. The results indicated 26 and 25% decreases in PT after concentric and eccentric exercises, respectively. This study was included for the information pertaining to the use of the author's isometric strength testing and signal processing.

Behm, 1995.

Strength gains have been attributed to neural adaptations such as alterations in recruitment, rate coding, synchronization of motor units, reflex potentiation, co-contraction of antagonists, and synergistic muscle activity. Although most training studies show increases in EMG, a few have shown increase in strength with no apparent changes in neural drive. This may highlight the importance of motor control and the reorganization of supraspinal inputs. High intensity concentric and eccentric contractions with arousal and imagery techniques merit further study in promoting optimal neural adaptations. Most velocity specificity studies have emphasized movement rather than contraction speed, which may be the predominant factor. The high rate of force development achieved with explosive contractions should serve as a template for power training. The extent of muscle hypertrophy is dependent upon protein degradation and synthesis, which may be enhanced through high intensity, high volume eccentric and concentric contractions.

Bilodeau et al., 2001.

The aim of this study was to assess differences in fatigue-related responses of neuromuscular function between younger and older healthy adults. Measures reflecting changes in voluntary activation, neuromuscular propagation, metabolite build-up, and excitation-contraction coupling processes were taken before, during, and after a sustained maximum elbow-flexion fatigue task which consisted of maintaining a maximum elbow flexion effort until the torque dropped below 50% of the participants maximal voluntary contraction (MVC). The authors found a greater role for failure in voluntary activation (central fatigue) in about half of the older subjects compared with zero of the younger subjects to explain the decrease in force-generating capacity with sustained activity. In contrast, similar behaviors in measures reflecting changes in peripheral mechanisms were noted for the two age groups. The results point to a potential shift in fatigue mechanisms with age, such as central fatigue seems to be affected greater for older male adults compared to younger males.

Bishop et al., 1999.

Obstacle courses (OCs), physical challenge courses, and confidence courses are valuable in training and assessing military troops. However, OCs are not well characterized with regard to physical demands and requisite abilities. The purpose of this study was to evaluate the physical capabilities associated with success on an OC. Male subjects (N = 47) were assessed on an OC, skinfolds, upper and lower body aerobic and anaerobic power, muscular strength, and endurance. Faster performers were lighter, leaner, and relative to body weight, averaged greater arm anaerobic peak and mean power, leg aerobic power, one-repetition maximum leg press, and one-repetition maximum latissimus dorsi pull-down, than slower performers. There were significant correlations between OC time and weight, percent fat, anaerobic leg mean power, arm anaerobic peak and mean power, and arm and leg aerobic power , all expressed relative to body weight. A three-variable regression model accounted for 35% of the variation in OC time. Good performers on this OC displayed many diverse physical capabilities.

Bishop et al., 2008.

The impact of body weight on test scores is a common issue in applied measurement. Dimensional analysis suggests that heavier participants are disadvantaged in weight-supported tasks. The purpose of this study was to evaluate the impact of body weight on performance scores for a military obstacle course. Three cohorts of male participants completed the Indoor Obstacle Course Test (IOCT). In cohort 1 (N = 2,191), height and weight were measured. In cohort 2 (N = 134), skinfold measurements were also performed. In cohort 3 (N = 44), all aforementioned measurements were performed, as well as upper- and lower-body tests for aerobic power, anaerobic power, muscular strength, and muscular endurance. The R2 between IOCT scores and body weight was 0.06 and that between IOCT scores and percentage of body fat was 0.08. All cohort analyses suggested that, for male subjects, body weight had only a small impact on the performance score distribution and the IOCT is fit for purpose as a fair repeatable system for assessment of physical performance.

Campos et al., 2002.

Subjects in this study participated in an 8-week progressive resistance-training program to investigate the "strength–endurance continuum". Subjects were divided into four groups: a low repetition group (Low Rep) performing 3–5 repetitions maximum (RM) for four sets of each exercise with 3 min rest between sets and exercises, an intermediate repetition group (Int Rep) performing 9–11 RM for three sets with 2 min rest, a high repetition group (High Rep) performing 20–28 RM for two sets with 1 min rest, and a non-exercising control group (Con). Three exercises (leg press, squat, and knee extension) were performed 2 days/week for the first 4 weeks and 3 days/week for the final 4 weeks. Maximal strength and local muscular endurance were assessed at the beginning and end of the study. Maximal strength improved significantly more for the Low Rep group compared to the other training groups, and the maximal number of repetitions at 60% 1RM improved the most for the High Rep group. In addition, time to exhaustion significantly increased at the end of the study for only the High Rep group. All three major fiber types (types I, IIA, and IIB) hypertrophied for the Low Rep and Int Rep groups, whereas no significant increases were demonstrated for either the High Rep or Con groups. All three training regimens resulted in similar fiber-type transformations (IIB to IIA), the low to intermediate repetition resistance-training programs induced a greater hypertrophic effect compared to the high repetition regimen. The High Rep group appeared better adapted for submaximal, prolonged contractions, with significant increases in time to exhaustion. The present findings suggest that intensity and number of repetitions performed may dictate the physical and physiological adaptations that occur.

Caserotti et al., 2008.

This study investigated the effects of 12 weeks of explosive-type heavy-resistance training (75–80% of 1RM) protocol in old and very old women. Training was performed with maximal intentional acceleration of the training load during the concentric movement phase. MVC, rate of force development (RFD), impulse, and maximal muscle power were measured during a countermovement jump (CMJ) and during unilateral leg extension task (LEP). RFD, impulse, MVC, CMJ, and LEP increased in both groups. The authors findings revealed that explosive-type heavy-resistance training seems to be safe and well tolerated in healthy elderly women. Specifically, adaptive neuromuscular changes in selected physiological variables that are commonly associated with the risk of falls and disability in aged individuals.

Channell & Barfield, 2008.

The purpose of this study was to compare the effects of a ballistic resistance training program of Olympic lifts with those of a traditional resistance training program of power lifts on vertical jump improvement in male high school athletes. There was no significant mean difference among Olympic trained, power trained, and control groups, but large effect sizes between Olympic trained versus control and power trained versus control. This study suggests that both Olympic and power training are effective in improving vertical jump performance in male high school athletes. Findings from the study indicated that Olympic lifts as well as power lifts provide improvement in vertical jump performance and that Olympic lifts may provide a modest advantage over power lifts for vertical jump improvement in high school athletes.

Conchola et al., 2013.

The purpose of this study was to investigate the effects of a fatigue-inducing bout of submaximal, intermittent isometric contractions on the electromechanical delay (EMD) of the leg extensors and flexors in young and old men. Subjects performed MVCs followed by a fatigue-inducing protocol consisting of intermittent isometric contractions of the leg extensors or flexors using a 0.6 duty cycle (6 s contraction, 4 s relaxation) at 60 % of MVC until volitional fatigue. MVCs were again performed at 0, 7, 15, and 30 min post fatigue. The authors found differential fatigue induced EMD recovery patterns between the leg extensors and flexors with the flexors being slower to recover and also that age-related increases of EMD are muscle group specific.

Crombie et al., 2012.

To examine relationships between changes in body weight, body composition, and fitness level in male students of the general population and those in the Army Reserve Officer Training Corps (ROTC) program during the freshman year of college. Thirty-seven healthy, nonsmoking, first-semester resident male students were divided into 3 groups: low active (LA), high active (HA), and ROTC. Baseline (beginning of freshman year) and 6-month follow-up measurements included anthropometry, body composition (by DXA), 3-day food records, and physical activity (PA) assessment. Weight and body-mass index did not change significantly within or among groups. HA participants compared with LA and ROTC had a significant decrease in body fat. They also had a significant increase in lean mass compared with LA and ROTC. ROTC and LA participants were similar in all measures of body composition and PA and had significantly lower PA levels than the HA group. No significant relationships were observed between dietary variables and body-composition changes. These results suggest that higher PA was the most powerful determinant in achieving favorable body-composition outcomes. In addition, current physical training conducted by ROTC at Florida State University (which seems to be a practice nationwide) might not be sufficient to offset gains in body fat.

Fielding et al., 2002.

The purpose of this study was to see if a high-velocity resistance-training program would increase muscle power more than a traditional (TRT) resistance-training program. The authors used thirty women as their participants and randomly placed them into either a high-velocity or TRT group that trained for 16 weeks. Training was conducted three times per week and comprised of leg press and knee extension exercises. Results showed that muscle strength increased similarly in both groups, but the high-velocity group was able to generate higher power than the TRT group.

Gandevia, 1992.

Fatigue may be defined as a reduction in the maximal force-generating capacity of a muscle. It may result from peripheral processes distal to the neuromuscular junction and from central processes controlling the discharge rate of motoneurons. When assessed with a sensitive test using twitch interpolation, most MVCs approach but do not attain optimal muscle output. During fatigue, reflex inputs from intramuscular receptors may contribute to a decline in motor unit discharge rate or a decline which optimizes force production during maximal efforts.

Gist et al., 2015.

The objective was to determine the effects of high-intensity interval training (HIT) on fitness in Army Reserve Officers' Training Corps cadets. Twenty-six college-aged participants completed 4 weeks of exercise training 3 days per week consisting of either approximately 60 minutes of typical physical training or HIT whole-body calisthenics involving 4 to 7 sets of 30-second "all out" burpees separated by 4 minutes of active recovery. Several pre- and post-intervention fitness variables were compared. We observed no changes across time or differences between groups in aerobic capacity, anaerobic capacity, or Army Physical Fitness Test performance. However, there was a significant Group × Time interaction for skeletal muscle mitochondrial function (Tc: time constant of recovery). For the typical physical training group, the authors observed improved mitochondrial function; whereas, mitochondrial function decreased in HIT. HIT sustained fitness despite the short duration and reduced volume of activity. A program that includes HIT as part of a larger program may be well suited for maintaining fitness in moderately trained armed forces personnel without access to equipment.

Hakkinen & Keskinen, 1989.

Male elite strength-trained athletes (SA), elite sprinters (SPA) and elite endurance-trained athletes (EA) volunteered for examination of their muscle cross-sectional area (CSA) using an ultrasonic apparatus, maximal voluntary isometric force using a dynamometer, force-time and relaxation-time characteristics of the KE muscles. The SA group demonstrated slightly greater CSA and maximal absolute strength than the SPA group, while the EA group demonstrated the smallest values both in CSA and especially in maximal strength .When the maximal forces were related to CSA of the muscles, the mean value for the SA group of remained slightly greater than that recorded in the SPA group and significantly greater than that recorded in the EA group. The mean value in the SPA was also significantly greater than that of the EA group. The isometric force-time curves differed between the groups so that the times taken to produce the same absolute force were the shortest in the SPA group and the longest in the EA group. With force expressed as a percentage of the maximum, the force-time curves showed that the SPA group demonstrated still shorter times to a given value, especially at the lower force levels, than the other two groups. With regard to the differences in force production the rate and amount of neural activation of the muscles and/or in the qualitative characteristics of the muscle tissue itself. The results characterize the very specific nature of high resistance strength-, sprint- and endurance-training over a prolonged period of time.

Hooper et al., 2013.

Resistance training has been found to have a multitude of benefits. However, when performed with short rest, resistance training can result in substantial fatigue, which may have a negative impact on exercise technique. The purpose of this study was to examine the effects of fatigue from resistance exercise on joint biomechanics to determine what residual movement effects may exist after the workout. Twelve men with at least 6 months of resistance training experience performed 5 body weight squats before and after (Pre,Post) a highly fatiguing resistance training workout, which consisted of 10 sets at 75% of 1RM for the back squat, bench press, and deadlift. Peak angle, total displacement, and rate of movement were assessed for knee flexion, trunk flexion, hip flexion, hip rotation, and hip adduction. Upon completion of the fatigue protocol, it was found that a significant decrease in peak angle was observed for knee flexion, hip flexion, and hip adduction. Further, there was a significant reduction in angular displacement for knee flexion, hip flexion, hip adduction, and hip rotation. Lastly, a significant reduction in displacement rate for knee flexion, hip flexion, hip adduction, and hip rotation were also observed. This study demonstrated that there are acute effects on movement capabilities after a high-intensity short rest protocol.

Izquierdo et al., 2009.

This study examined the effects of heavy resistance training on dynamic exercise-induced fatigue tasks after two loading protocols with the same relative intensity and absolute load in pre-training in men. Maximal strength, muscle power, surface EMG was measured before and after exercise. After training, when the relative intensity of the fatiguing dynamic protocol was kept the same, the magnitude of exercise-induced loss in maximal strength was greater than that observed before training. The peak power lost after was greater than the corresponding exercise-induced decline observed in isometric strength. However, after training the muscle is relatively able to work more before task failure. The results of this study may indicate that rate of fatigue development (i.e., power and MVC) was faster and more profound after training despite using the same relative intensity.

Jones et al., 2012.

The United States Army administers fitness tests and collects height and weight data for soldiers and cadets in order to determine a measure of physical readiness. This study examined individual test results from the U.S. Army’s Physical Fitness Test (PFT) and respective Body Mass Index (BMI) to see if any association existed in male ROTC (Reserve Officer Training Corps.) cadets. If a correlation was found between BMI and PFT scores, then leaders could more accurately predict how an individual would perform on an upcoming fitness evaluation. 145 male (age 17-31) ROTC college students’ PFT scores and BMI measurements were analyzed via a Pearson Correlation Coefficient to determine if a meaningful correlation existed between them. Raw and point adjusted (percentiles) scores were evaluated. There was no meaningful relationship found between

BMI and an individual’s respective scores on push-ups, sit-ups, or two mile run times. BMI is not an accurate predictor of Army PFT scores for male cadets.

Jozsi et al., 1999.

It is suggested that muscle power diminishes with increasing age and inactivity. However, the capacity for older adults to increase muscle power with resistance exercise has not been fully examined. For the present study, the authors examined the influence of progressive resistance training on muscle power output in young and old males and females. All subjects performed 12 weeks of the training at a workload equivalent to 80% of the one repetition maximum (1RM). Participants performed five exercises, three sets per exercise, twice weekly. Muscle power was measured at resistances equivalent to 40, 60, and 80% of the 1RM, on the knee extension and arm pull machines (i.e., latissimus pulldowns and seated rows). All subjects increased arm pull power similarly at 40 and 60% of 1RM, independent of age or sex. There was not a significant increase in arm pull power at 80% of 1RM. Older and younger subjects also had similar absolute increases in leg extensor power at 40 and 60% of 1RM, but men responded with greater absolute gains than women at these percentages. The increase in leg extensor power at 80% of 1RM was similar in all groups. Older and younger subjects increased strength similarly in all exercises except the left knee extension. Independent of age, men increased strength more than women in all exercises except the double leg press. The results found by the authors may demonstrate that older individuals can still improve muscle power (and strength); however, men may realize greater absolute gains than women.

Judge et al., 2003.

The aim of this study was to assess the effects of variations in the volume and intensity of resistance training through a 16-week training program in highly skilled athletes on neural adaptive mechanisms. The pattern of neural drive was measured by analyzing isometric torque-time curves and EMG characteristics during the performance of rapid isometric contractions at maximal effort. The volume and intensity of training were varied at 4-weekly intervals to systematically emphasize the development of strength, power and motor performance in 14 highly skilled track and field athletes. KE strength increased significantly by 15% during steady maximal isometric contractions and by 24% during rapid isometric contractions at maximal effort after the 16-week training program. Increases in EMG amplitude and rate of EMG activation indicated that improvements to the pattern of neural drive occurred with sport-specific resistance training. The maximal and pattern of neural drive did not change in the control group.

Lattier et al., 2003.

This study tested the hypothesis that neuromuscular characteristics of plantar flexor (PF) and KE muscles explain differences of both performance in vertical jump and MVC between endurance-trained (END), power-trained (POW), and sedentary subjects

(SED). Evoked twitch characteristics of PF and KE were measured. MVC, maximal voluntary activation (%VA) of KE, and performance in vertical jump were also measured. POW have higher maximal rate of twitch force development (MRFD) than SED and END for both PF and KE; %VA and MVC were higher for POW and END than SED. Higher performances were measured in vertical jump for POW compared with END and SED. Significant relationships were found between the squat jump performance and MRFD for both KE and PF. These findings show that low MRFD on lower limbs extensors does not limit expression of MVC on subjects with high levels of activation.

Liguori, Krebsbach, & Schuna, 2012.

During the academic year, Army ROTC cadets are required to participate in mandatory physical training; however, during summer months training is not required. The purpose of this study was to determine if there is a change in cadet VO_{2max} after the summer when training is not mandatory. Participants completed a graded exercise treadmill test to determine their VO_{2max} in late spring of 2010 and again in early fall of 2010. Results indicated that over a three-month break from mandatory physical training, a significant decrease in VO_{2max} was seen for both genders in ROTC cadets.

Mathiassen, 1989.

For this study participants completed 15 tests, comprising 120s of repeated, maximal isokinetic knee extensions. The tests differed with respect to movement velocity

($30°·s^{-1}$, $120°·s^{-1}$, and $300°·s^{-1}$), and movement frequency (5 at each velocity). At a given exercise time ratio, increasing movement velocity produced increasing fatigue. However, at a given muscular power output, fatigue developed to a greater extent at the low velocity than at the two higher ones, which did not differ significantly. Additionally, individual variation was seen in the positions of the low-, medium-, and high-velocity lines. These variations did not depend on the training background. The author claimed that this implies that the validity of using single-velocity, single-frequency tests in determining isokinetic endurance is doubtful, and further suggests incorporating multiple movement speeds for isokinetic testing for basic physiological research, and assessments of muscular performance.

McCaulley et al., 2009.

The purpose of this study was to determine the acute neuroendocrine response to hypertrophy (H), strength (S), and power (P) type resistance exercise (RE) equated for total volume. Subjects completed three RE protocols and a rest day (R). The protocols included (1) H: 4 sets of 10 repetitions in the squat at 75% of 1RM (90 s rest periods); (2) S: 11 sets of three repetitions at 90% of 1RM (5 min rest periods); and (3) P: 8 sets of 6 repetitions of jump squats at 0% of 1RM (3 min rest periods). Peak force, RFD, and muscle activity from the vastus medialis (VM) and biceps femoris were determined during a maximal isometric squat test. The percent of baseline muscle activity of the VM immediately post was significantly greater following the H compared to the S protocol. It appears the H protocol elicits a unique pattern of muscle activity as well. RE protocols of varying intensity and rest periods elicit different acute neuroendocrine responses which indicate a unique physiological stimulus.

Murray et al., 2007.

The purpose of this investigation was to determine the effects of 4 weeks of slow ($60^{o}\cdot s^{-1}$) vs. fast ($400^{o}\cdot s^{-1}$) velocity training on rate of velocity development (RVD), PT, and performance. Twenty male students were tested, before and after 4 weeks of training, for PT production, RVD (at 60, 180, 300, 400, and $450^{o}\cdot s^{-1}$), standing long jump distance, and 15- and 40-m sprint times. All participants underwent 8 training sessions, performing 5 sets of 5 repetitions of simultaneous, bilateral, concentric knee extension exercises on a Biodex System 3 isokinetic dynamometer at either 60^{o} or $400^{o}\cdot s^{-1}$. The results of these authors study support the suggestion that there is a significant neural adaptation to short-term isokinetic training performed by recreationally trained males, producing changes in limb acceleration and performance with little or no change in strength.

Newton et al., 2008.

This study compared resistance-trained and untrained men for changes in commonly used indirect markers of muscle damage after maximal voluntary eccentric exercise of the elbow flexors. The trained men were classified as one’s who performed EF exercises at least three training sessions per week, while the 15 untrained men did not perform any resistance training for at least 1 year. For the testing protocol, all subjects performed 10 sets of 6 maximal voluntary eccentric actions against the lever arm of an isokinetic dynamometer moving at a constant velocity of $90°\cdot s^{-1}$. Specific variables that were assessed were before, immediately after, and for 5 days after exercise were maximal voluntary isometric and isokinetic torque, range of motion, upper arm circumference, plasma creatine kinase activity, and muscle soreness. Results suggest the trained group showed significantly smaller changes in all of the measures except for muscle soreness and faster recovery of muscle function compared with the untrained group. These results suggest that resistance-trained men are less susceptible to muscle damage induced by maximal eccentric exercise than untrained subjects.

Newton et al., 1999.

The purpose of this study was to determine whether ballistic resistance training would increase vertical jump performance of already highly trained jump athletes. Male volleyball players from a NCAA Division I team participated in the study. Standing vertical jump and reach along with jump and reach from a three-step approach were measured. Several types of vertical jump tests were also performed to measure force, velocity, and power production during vertical jumping. All participants completed the usual preseason volleyball on-court training combined with a resistance training program and were split into a treatment and control group. The treatment group completed 8 weeks of squat jump training while the control group completed squat and leg press exercises. Both groups were retested at the completion of the training period. The treatment group produced a significant increase in both types of jumps. These increases were significantly greater compared to the control group who did not observe any differences from pre to post testing. The authors observed that ballistic resistance-training increased overall force output during jumping, and in particular increased rate of force development were the main contributors to the increased jump height. The results of this study offer support to the effectiveness of ballistic resistance training for improving vertical jump performance in elite jump athletes.

Newton, et al., 2002.

This study investigated the effects of mixed-methods resistance training on young and older men to determine whether similar increases in muscle power would occur. Specifically, 10 weeks of a periodized resistance-training program was designed to increase muscle size, strength, and maximal power for isometric squat strength, time course of force development, muscle fiber characteristics, and muscle activation (iEMG), as well as force and power output during squat jumps, were compared in young (YM) and older men (OM). Isometric squat strength was higher in the YM compared with OM at all testing occasions and increased over the training period. The early phase of the force-time curve was shifted upward in both groups over the course of the training. During the squat jumps, the YM produced higher force and power at all test occasions and at all loads tested compared with the OM. Both the YM and OM group increased power output for the 17 kg, and 30% and 60% 1RM loads. Although the results of this study confirm age-related reductions in muscle strength and power, the older men did demonstrate similar capacity to young men for increases in these variables.

Nguyen et al., 2009.

Eccentric muscle actions have been shown to induce muscle damage and lead to delayed-onset muscle soreness (DOMS), which may impair performance. The purpose of this study was to examine the effect of DOMS on elbow flexion strength and RVD. Participants performed 6 tests (pre- and post-eccentric and every 24 hours for 4 days). In the pre-eccentric tests, each participant did 5 concentric repetitions of EF/EE on an isokinetic dynamometer at $240°\cdot s^{-1}$. Each subject then completed 6 sets of 10 eccentric EF actions at $30°\cdot s^{-1}$ and finished with a post-eccentric test with another 5 concentric repetitions at $240°\cdot s^{-1}$. On days 1-4, each participant did 5 more repetitions at $240°\cdot s^{-1}$. PT scores on the post-eccentric test and day 1 were both significantly less than on the pre-eccentric test. The RVD scores on the post-eccentric test, day 1, and day 2 were all significantly less than on the pre-eccentric test. From these results the authors suggest that muscle damage and soreness (DOMS) may cause significant decreases in elbow flexion concentric strength and RVD.

Oliver et al., 2017.

The purpose of this study was to determine the effect of physical readiness training (PRT) over the course of an academic year (9 months) in freshman ROTC cadets. body composition, 1-repetition maximum bench and squat, countermovement vertical jump, maximal aerobic capacity and the Army Physical Fitness Test (APFT) measures of performance before, mid-year , and at the conclusion of the academic year. No changes occurred in body composition, VO2max, or countermovement vertical jump. Nine months of PRT improved APFT scores of freshmen cadets while minor effects were noted in laboratory-based performance. Given the lack of improvements in strength and power, the authors concluded that it would be advisable to provide supplemental strength and power training.

Paasuke et al., 1999.

The purpose of this study was to investigate the neural and muscular changes during fatigue produced in repeated exhaustive submaximal static contractions in subjects with different physical training status. Three groups of differently adapted male subjects (power-trained, endurance-trained and untrained) performed 10 sets of repetitive submaximal isometric contractions at 40% of their maximal voluntary contraction (MVC) force till exhaustion was achieved. One-minute rest periods were allowed between each set. Results indicate that the endurance-trained athletes had a significantly longer holding times for all 10 trials compared with power-trained athletes and untrained subjects.

However, no significant differences in static endurance between power-trained athletes and untrained subjects were noted.

Pereira & Gomes, 2003.

Recommendations for resistance training include the number of exercises, sets, repetitions, and frequency of training, but ambiguously mention movement velocity. For example, different velocities suggest different performances (i.e. a different number of repetitions or different loads). The authors claim studies investigating the effect of different movement velocities on resistance training have not reached a consensus. Some studies indicate specificity in strength gains while others indicate generality, and that some indicate slow training to be better, while others indicate fast training or indicate no differences. Although a wide variety of instruments were used throughout testing (hydraulic equipment, dynamometer) the results seem to suggest that no differences are observed between velocities. Being able to define the training velocity is mostly important for athletic performances where a wide range of velocities are needed, and transfer of gains would greatly optimize training. Furthermore, at the other end of the spectrum, there are the elderly, to whom power loss may impair even daily functions, but training with fast velocities might increase injury risk and, therefore, transfer of gains from slow training would be greatly beneficial.

Schiotz et al., 1998.

This study examined the effects of manipulating training intensity on strength, body composition, and performance in trained ROTC cadets. Fourteen male ROTC cadets were pre-and post-tested for % body fat and 1-RM strength on the bench press and parallel squat. Performance was measured via the physical fitness components of the Army Ranger Challenge and consisted of push-ups, sit-ups, 2-mile run, and 10-km ruck-run. Subjects were matched according to military experience and randomly assigned to a periodized model or a constant-intensity model for 10 weeks of resistance training. Total training volume was equal between groups. The periodized group significantly increased in 1-RM bench press, 1-RM parallel squat, and push-ups, and significantly decreased % fat and ruck-run time. The constant-intensity group significantly increased 1-RM parallel squat and push-ups, and significantly decreased their 2-mile run and ruck-run time. The periodized group completed the ruck-run significantly faster than the constant-intensity group. The results indicate that following a 10-week training cycle with trained subjects, significant improvements in body composition, strength, and performance can be obtained using two different training programs that have equal total relative training volume.

Steed et al., 2016.

The Army Physical Fitness Test (APFT), including timed push-ups, sit-ups, and run, assesses physical performance for the Army. Percent body fat is estimated using height and circumference measurements. The objectives of the study were to (a) compare the accuracy of height and circumference measurements to other, more accepted, body fat assessment methods and (b) determine the relationships between body composition and APFT results. Participants included Reserve Officer Training Corps (ROTC) cadets (n = 11 males, 2 females). Percent body fat was assessed using height and circumference measurements, air-displacement plethysmography, and bioelectrical impedance analysis. APFT results were provided by the ROTC director. All assessment methods for percent body fat were strongly associated, implying that height and circumference measurement is a practical tool to estimate percent body fat of ROTC cadets. Total APFT score was not associated with any body fat assessment method. Push-up number was negatively associated with percent body fat by all assessment methods, although run time was positively associated. This suggests that percent body fat may be an important variable in determining or improving cardiovascular and muscular endurance, but not APFT performance.

Stock et al., 2011.

The purpose of this study was to examine the effects of diverting activities on recovery from fatiguing concentric isokinetic muscle contractions. On 3 separate occasions, participants performed 2 bouts of 50 consecutive maximal concentric isokinetic muscle contractions of the dominant leg extensors. Between these bouts, the participants either performed a mental diverting activity, physical diverting activity, or rested quietly. For each trial, the peak torque data from the first and second bouts of 50 muscle actions served as the pretest (Pre) and posttest (Post) data. The results indicated that when the participants rested quietly or performed the physical diverting activity between the fatiguing bouts, the initial peak torque values observed for Post were significantly less than those for Pre. Participants who performed math problems showed no decline in the initial peak torque values, indicating better recovery. Additionally, a decline in the average torque values was observed from Pre to Post for those who rested quietly, but not for those who had mental or physical diverting activities. No differences were observed among the trials for final peak torque, percent decline, or the linear slope of the decline in peak torque. The authors findings demonstrated that performing either mental or physical diverting activities after fatiguing isokinetic muscle actions enhanced recovery.

Stock et al., 2013.

This study compared the relative peak torque and normalized EMG mean frequency (MNF) responses during fatiguing isokinetic muscle actions for men versus women. Subjects performed 50 maximal concentric isokinetic muscle actions of the leg extensors at a velocity of $180°\cdot s^{-1}$ while surface EMG signals were detected from the vastus lateralis, rectus femoris, and vastus medialis. The variables assessed were initial, final, and average peak torque; percent decline; the estimated percentage of fast-twitch fibers for the vastus lateralis; and the linear slope coefficients and y-intercepts for normalized EMG MNF versus repetition number. The mean initial, final, and average peak torque values for men were greater than those for women. There were no mean differences for percent decline and the estimated percentage of fast-twitch fibers for the vastus lateralis. Men demonstrated greater peak torque values than those for women, but the declines in peak torque and normalized EMG MNF were similar between the sexes. The vastus medialis was more fatigue-resistant than both the vastus lateralis and rectus femoris.

Thomas et al., 2004.

One role of Army Reserved Officer's Training Corps (ROTC) programs is to physically prepare cadets for the demands of a military career. Cadets participate in physical training 3 days per week as part of their military science curriculum. Limited research has been conducted on the fitness level of ROTC cadets; therefore, the purpose of this study was to profile the physical fitness status of a cadre of ROTC cadets. Forty-three cadets (30 men and 13 women) performed Army Physical Fitness Test (APFT) assessments (2-mile run, 2-minute maximum push-ups and sit-ups) and clinical assessments of fitness (Bruce protocol Vo(2)max, underwater weighing, and 1 repetition maximum [1RM] bench press tests). Mean +/- standard deviations were calculated to provide the physical fitness profile for each parameter. The mean scores were above the 83rd percentile on all APFT items and average (percent fat) to above average (Vo(2)max and men's bench press scores) when compared with peer-age and sex-corrected norms. Only the women's bench press score was below average. With the exception of the women's bench press, these ROTC cadets possessed average to above average levels of fitness.

Crawford et al., 2011.

The purpose of this study was to compare physical and physiological fitness test performance between Soldiers meeting the Department of Defense (DoD) body fat standard (≤18%) and those exceeding the standard (>18%). Ninety-nine male 101st Airborne (Air Assault) Soldiers were assigned to group 1: ≤18% body fat (BF) or group 2: >18% BF. Groups 1 and 2 had similar amounts of fat-free mass (FFM) (66.8 ± 8.2 vs. 64.6 ± 8.0). Each subject performed a Wingate cycle protocol to test anaerobic power and capacity, an incremental treadmill maximal oxygen uptake test for aerobic capacity, isokinetic tests for knee flexion/extension and shoulder internal/external rotation strength, and the Army Physical Fitness Test. Results showed group 1: ≤18% BF performed significantly better on 7 of the 10 fitness tests. In Soldiers with similar amounts of FFM, Soldiers with less body fat had improved aerobic and anaerobic capacity and increased muscular strength.

DeMaio et al., 2009.

The load of personal protective equipment (PPE) body armor affects physical performance of trained military personnel. A balanced effect of injury prevention and performance optimization is desired. To assess PPE on physical performance by cardiovascular, balance, strength, and functional field tests. Twenty-one physically active U.S. military volunteers on active duty participated in an experimental repeated measures counter-balanced design study. All subjects completed a battery of physical performance tests with and without a PPE system of Kevlar front and back plates and an unlined combat helmet. Aerobic capacity (VO2max), upper extremity climbing strength, balance, and functional field tests including anaerobic running (300 yard shuttle run), agility (box agility), and upper extremity power (rope pull and dummy drag) were evaluated. Treadmill time was significantly reduced by PPE. Upper extremity climb data showed a significant effect of PPE on the number of repetitions. Postural sway in both the AP and ML directions increased after fatigue and when the subject was wearing PPE. Analysis of field tests revealed significant differences between PPE and control conditions for the shuttle run, but no significant differences for the box agility test or upper extremity power rope pull and dummy drag test.

Giovannetti et al., 2012.

These authors evaluated injuries and level of fitness among a large population-based sample of USAF men and women aged 18 to 60 years from 2003 to 2005. Aerobic capacity was estimated by submaximal cycle ergometry fitness test and the 1.5-mile run. There was an increase of 6.04 mL/kg/min in approximate maximal oxygen uptake (VO2 max) for men and 3.25 mL/kg/min for women with the run test results versus the cycle ergometry test. The results showed increased injuries and higher VO2 max scores during the implementation of a new “Fit to Fight” fitness program.

Griffith et al., 2018.

Using a 5.38 million record database from the Air Force Fitness Management System, the authors evaluated how waist circumference (WC), body mass index (BMI), waist-to-height ratio (WHtR), and height-to-weight (H-W) correlate with fitness as assessed by the 1.5-mile run in addition to total fitness, which incorporates the 1.5-mile run time, number of push-ups and sit-ups. Approximately 18% of the 5.38 million records belonged to women. With respect to sex differences, males appeared noticeably faster and performed more push-ups on average than females. The number of sit-ups completed was more comparable, with males having a slight advantage. Males also appeared to have larger WC, BMI, H-W, and WHtR measurements. Whether individually or adjusting for age and sex, WHtR performed better than the other body composition variables. The authors proposed using a WHtR scoring system instead of the current usage of the WC system.

Heinrich et al., 2012.

Appropriate and effective physical fitness training is imperative for soldier survival and mission success. The purpose of this study was to determine the effects of Mission Essential Fitness (MEF) circuit-style training program compared to standard

Army Physical Readiness Training (APRT) on fitness, physiological, and body composition changes. Active duty Army personnel were randomly assigned to two groups (MEF = 34 or APRT = 33) for 8 weeks of training (15 sessions each). The MEF program included functional movements focused on strength, power, speed, and agility. Fifteen exercises were performed continuously for 60 to 90 seconds for 45 minutes. Baseline and post-test measures included the Army physical fitness test, physiological indicators, body composition, and additional fitness indicators. MEF participants significantly increased their push-ups, bench press, and flexibility and significantly decreased their 2-mile run and step test heart rate compared to participants doing APRT. Both groups maintained body composition and reported no injuries. The MEF training program safely improved muscular strength and endurance, cardiovascular endurance, and flexibility, supporting functional fitness circuit-style exercise training for military personnel.

Henning, Khamoui, & Brown, 2011.

The purpose of this article was to overview the physical demands of basic combat training (BCT) and present guidelines for strength and conditioning professionals tasked with training recruits. The tasks associated with BCT span the entire performance spectrum, including aerobic capacity, anaerobic capacity, strength, power, and muscular endurance. Prospective recruits entering BCT without adequate strength and endurance conditioning may be predisposed to failing the Army physical fitness test and/or obtaining musculoskeletal injuries, resulting in subsequent discharge from the Army.

Hydren, Borges, & Sharp, 2017.

Physical performance tests (e.g., physical employment tests, return-to-duty tests) are commonly used to predict occupational task performance to assess the ability of individuals to do a job. The purpose of this systematic review was to identify predictive tests that correlate well with maximal lifting capacity in military personnel. The predictive tests were categorized into 10 fitness domains: body mass and composition, absolute aerobic capacity, dynamic strength, power, isometric strength, strength-endurance, speed, isokinetic strength, flexibility, and age. Lean body mass (kg) was the strongest overall predictor. Tests of dynamic strength had stronger correlations than strength endurance. Anthropometric measures explained 24–54% of maximal lift capacity variance, and lean body mass alone accounted for ∼69%. This review provides summarized information to assist in the selection of predictive tests for maximal lifting capacity in military personnel.

Knapik et al., 1990.

Male infantry soldiers were studied before, during, and after a 5-day simulated combat exercise. During the exercise, subjects were rated on their field performance by senior infantry non-commissioned officers. Prior to the exercise, direct measures of body composition and maximal oxygen uptake were obtained. Before and after the exercise the Army Physical Fitness Test and various measures of anaerobic capacity (Wingate and Thorstensson tests) and muscular strength (isometric and isokinetic) were obtained. Results showed no significant decrement in field performance during the exercise. Upper-body anaerobic capacity and strength declined following the exercise, although the results for upper-body strength were not consistent on all measures. Field performance was significantly correlated with measures of upper-body anaerobic capacity and strength. Upper-body strength and anaerobic capacity appear to be important for infantry operations and subject to declines during combat operations.

Knapik et al., 2003.

This study examined injury and physical fitness outcomes in Basic Combat Training (BCT) during implementation of Physical Readiness Training (PRT). PRT is the U.S. Army's emerging physical fitness training program. An experimental group (EG), which implemented the PRT program, was compared to a control group (CG), which used a traditional BCT physical training program during the 9-week BCT cycle. Injury cases were obtained from recruit medical records and physical fitness was measured using the U.S. Army Physical Fitness Test (APFT, consisting of push-ups, sit-ups and a two-mile run). There were no differences between groups for traumatic injuries. On the first administration of the final APFT, the EG had a greater proportion of recruits passing the test than the CG. After all APFT retakes, the EG had significantly fewer APFT failures than the CG among the women, and the EG had an overall higher pass rate. The PRT program reduced overuse injuries and allowed a higher success rate on the APFT.

Knapik et al., 2006.

This article defines physical fitness and then reviews the literature on temporal trends in the physical fitness of new US Army recruits. The limited data on recruit muscle strength suggested an increase from 1978 to 1998. Data on push-ups and sit-ups suggested no change in muscular endurance between 1984 and 2003. Limited data suggested that maximal oxygen uptake (V̇O2max; mL/kg/min) of male recruits did not change from 1975 to 1998, while there was some indication of a small increase in female recruit V̇O2max in the same period. Recruit height, weight and body mass index have progressively increased between 1978 and 2003. Both the body fat and fat-free mass of male recruits increased from 1978 to 1998; however, body composition data on female recruits did not show a consistent trend. This article indicates that temporal trends in recruit fitness differ depending on the fitness component measured. The very limited comparable data on civilian populations showed trends similar to the recruit data.

Knapik et al., 2009.

This paper reviews the rationale and evaluations of Physical Readiness Training (PRT), the new U.S. Army physical training doctrine designed to improve soldiers' physical capability for military operations. The purposes of PRT are to improve physical fitness, prevent injuries, progressively train soldiers, and develop soldiers' self-confidence and discipline. The PRT follows the principles of progressive overload, regularity, specificity, precision, variety, and balance. The standard list of military tasks and determining 1) the physical requirements, 2) the fitness components involved, and 3) the training activities that most likely could improve the military tasks were examined. In 3 military field studies, the overall adjusted risk of injury was 1.5-1.8 times higher in groups of soldiers performing traditional military physical training programs when compared with groups using a PRT program. Scores on the Army Physical Fitness Test were similar or higher in groups using PRT programs. In an 8-week laboratory study comparing PRT with a weightlifting/running program, both programs resulted in major improvements in militarily relevant tasks. When compared with traditional military physical training programs, PRT consistently resulted in fewer injuries and in equal or greater improvements in fitness and military task performance.

Knapik, Sharp, & Steelman, 2018.

A systematic literature search was conducted to identify and analyze articles that reported on physical fitness of new US Army recruits. Studies were selected if they involved recruits in Basic Combat Training or One-Station Unit Training, provided a quantitative assessment of at least one fitness measure, and the fitness measure(s) were obtained early in training. The authors analysis indicated little temporal change in height, but body weight, body mass index, body fat, and fat-free mass increased over time.

Muscular endurance (push-ups, sit-ups) demonstrated little systematic change over time. Limited but multiple measures of muscular strength suggest a temporal increase in strength. Specific components of US Army recruit fitness seem to have changed over time.

Kraemer et al., 2004.

The purpose of this study was to determine the effects of high intensity endurance training (ET) and resistance training (RT) alone and in combination on various military tasks. Thirty-five male soldiers were randomly assigned to one of four training groups: total body resistance training plus endurance training (RT + ET), upper body resistance training plus endurance training (UB + ET), RT only, and ET only. Training was performed 4 days per week for 12 weeks. Testing occurred before and after the 12-week training regimen. All groups significantly improved push-up performance, whereas only the RT + ET group did not improve sit-up performance. The groups that included ET significantly decreased 2-mile run time, however, only RT + ET and UB + ET showed improved loaded 2-mile run time. Leg power increased for groups that included lower body strengthening exercises (RT and RT + ET). Army Physical Fitness Test performance, loaded running, and leg power responded positively to training, however, it appears there is a high degree of specificity when concurrent training regimens are implemented.

Kraemer & Szivak, 2012.

This paper demonstrates that past training philosophies that no longer serve the modern warfighter. Training approaches for integration of strength with other needed physical capabilities have been shown to require a periodization model that has the flexibility for changes and is able to adapt to ever-changing circumstances affecting the quality of workouts. Additionally, sequencing of workouts to limit overreaching and development of overtraining syndromes that end in loss of duty time and injury are paramount to long-term success. Allowing adequate time for rest and recovery and recognizing the negative influences of extreme exercise programs and excessive endurance training will be vital in moving physical training programs into a more modern perspective as used by elite strength-power anaerobic athletes in sports today.

Laing Treloar & Billing, 2011.

This study examined the effects of load carriage on performance of an explosive, anaerobic military task. A task-specific assessment requiring five 30-m timed sprints was utilized. Seventeen soldiers underwent the test with two experimental conditions: unloaded (combat uniform and boots) and loaded (unloaded plus 21.6 kg fighting load, comprising webbing, weapon, helmet, and combat body armor). When loaded, there was a significant increase in the mean 30-m sprint time compared to unloaded. Of the total increase in mean sprint time, 51.7% occurred within the first 5 m. Female sprint times were affected to a larger extent than male as a result of the increased load. Fighting load significantly affected soldier mobility when conducting explosive, anaerobic military tasks, particularly among females. The authors determined that specific physical conditioning should be considered to minimize this effect.

Lester et al., 2010.

This investigation evaluated the effects of a 13-month deployment to Iraq on body composition and selected fitness measures. Seventy-three combat arms soldiers were measured pre- and post-deployment. Body composition was assessed by dual X-ray absorptiometry (DXA). Strength was measured by single repetition maximum (1-RM) lifts on bench press and squat. Power was assessed by a bench throw and squat jump. Aerobic endurance was evaluated with a timed 2-mile run. Exercise and injury history were assessed by questionnaire. Upper and lower body strength improved by 7% and 8%, respectively. Upper body power increased 9% and lean mass increased 3%. In contrast, aerobic performance declined 13% and fat mass increased 9%. Fewer soldiers participated in aerobic exercise or sports during deployment.

Macera et al., 2011.

The objective of this study was to identify changes in weight that occurred during deployment to Iraq or Kuwait between 2005 and 2008. Data on length and type of deployment among 16,365 male U.S. Navy personnel were combined with weight measurements before and after deployment from the Physical Readiness Information Management System. Weight measurements were available for 10,886 men who did not exceed Navy weight recommendations before deployment. In general, weight increased after deployment and, for those who did not exceed Navy recommendations before deployment, factors associated with weight gain included being enlisted and having a deployment longer than 228 days. Among 1,108 men with 2 deployments, a dwell time shorter than the combined deployed time was a risk factor for weight gain during the second deployment. Future studies should explore the combined effects of long deployments and short dwell times in maintaining the readiness of military personnel.

Nindl et al., 2002.

The purpose of this investigation was to characterize the impact of prolonged work, underfeeding, and sleep deprivation on physical and occupational related performance during military operational stress (SUSOPS). Soldiers were tested over a course of four days of a control and experimental week that included prolonged physical work, underfeeding, and sleep deprivation. Body composition was measured with dual-energy x-ray absorptiometry (DEXA). Ballistic power was assessed by 30 repetitive squat jumps and bench-press throws. Military-relevant occupational performance was evaluated with a 10-min box lift, obstacle course, grenade throw, rifle marksmanship, and a 25-min wall-build task. Fat-free mass (-2.3%) and fat mass (-7.3%) declined during SUSOPS. Squat-jump mean power (-9%) and total work (-15%) declined during SUSOPS. Bench-press power output, grenade throw, and marksmanship for pop-up targets were not affected. Obstacle course and box-lift performances were lower.

Pierce et al., 2018.

The purpose of this study was to assess soldier physical performance and military-specific task/fitness performance stratified by BMI. Soldiers performed a wide-array of physical fitness tests and military-specific tasks, including the Army physical fitness test (APFT). BMI stratification (higher vs. lower BMI) was associated with significant improvements in muscular strength and power, but also with decrements in speed/agility in male and female soldiers. Within the military specific tasks, a higher BMI was associated with an increased APFT 2-Mile Run time; however, performance on a 1600-m Loaded March or a Warrior Task and Battle Drill obstacle course was not related to BMI in either sex. Military body composition standards require a careful balance between physical performance, health, and military readiness.

Roy et al., 2010.

Total force fitness is a state in which the individual, family, and organization can sustain optimal well-being and performance under all conditions. Physical fitness, an important component of total force fitness, is the amount of physical training required to achieve a physical work capacity. Due to the harsh environments and high physical work capacity required for mission tasks, military service members must sustain a more advanced level of physical fitness than the civilian population. To meet these high demands, physical fitness training must be split into four components: endurance, mobility, strength (including core strength), and flexibility. Both aerobic and anaerobic training need to be utilized. The four components of physical fitness training plus performance testing and injury surveillance/prevention must be well understood and included as part of all military physical fitness programs to ensure our service members are prepared to meet the physical demands of the mission without incurring injury.

Sharp et al., 2000.

This study examined the effectiveness of basic combat training (BCT) in improving the physical fitness of incoming soldiers and compared the physical fitness and trainability of current trainees to those measured in previous years. Soldiers (182 men and 168 women) were recruited from those entering two BCT battalions. Volunteers performed the following procedures before BCT: (1) continuous uphill treadmill running test of peak oxygen uptake (VO2peak); (2) one-repetition maximum (1-RM) isometric strength test of the lower body, upper torso and upright pulling strength; (3) 1-RM test of dynamic lifting strength; (4) dual-energy X-ray absorptiometry (DEXA) assessment of body composition; (5) anthropometric measurements (skinfolds and circumferences); (6) vertical jump; (7) photometric measurement of limb length and joint diameters; and (8) joint mobility measures. BCT resulted in improvements in aerobic capacity, body composition, muscle strength (minimal), body mass and % body fat increased.

Sharp et al., 2008.

This purpose of this study was to examine change in physical fitness and body composition after a military deployment to Afghanistan. Infantry soldiers were measured before and after a 9-month deployment to Afghanistan for Operation Enduring Freedom. Measurements included treadmill peak oxygen uptake (peak VO2), lifting strength, medicine ball put, vertical jump, and body composition estimated via dual-energy x-ray absorptiometry (percent body fat), absolute body fat, fat-free mass, bone mineral content, and bone mineral density. There were significant decreases in peak VO_2 (-4.5%), medicine ball put (-4.9%), body mass (-1.9%), and fat-free mass (-3.5 %), whereas percent body fat increased from 17.7% to 19.6%.

Almond et al., 2008.

Overweight and obesity are increasingly contributing to disease burden among military populations. The purpose of this study was to calculate and examine the prevalence of overweight and obesity among the veteran population. Data were obtained from the 2004 Behavioral Risk Factor Surveillance System. Overweight (body mass index >25 kg/m^2) prevalence in veterans was 73.3% for males and 53.6% for females. Obesity (body mass index >30 kg/m^2) prevalence in veterans was 25.3% for males and 21.2% for females. Veterans were no more likely to be overweight or obese than nonveterans. Despite previous participation in a culture and environment that selects for and enforces body weight standards, veterans have a high prevalence of overweight and obesity that is similar to general population estimates.

Dahn et al., 2011.

The purpose of the present study was to assess treatment effects of MOVE! Weight Management Program for Veterans by comparing the trajectory of change in weight postintervention (3, 6, and 12 months post enrollment) to a preintervention period (1, 3, and 5 years before enrollment). Veterans gained 2kg/year before enrolling in MOVE! There were similar increases in weight across sex, racial/ethnic groups, and treatment condition. Weight for participants in self-management support stabilized after enrollment whereas participants in supportive group sessions had an average weight loss of 1.6kg/year. Findings from this study support the need for a lifestyle modification program such as MOVE! in primary care settings to assist overweight and obese patients in managing their weight.

Fryar et al., 2016.

Limited national estimates of cardiovascular disease risk factors using physical measurements and reported veteran status in the U.S. civilian population have been reported. The purpose of this study was to compare the prevalence of cardiovascular disease risk factors among veteran and non-veteran men in the U.S. civilian population. Veterans were more likely than non-veterans to be obese (42.6% vs 33.7%). After adjustment for obesity, there was no difference in hypertension, dyslipidemia, diagnosed diabetes, or smoking between veteran and non-veteran men.

Goodrich & Hall, 2018.

Military service is a formative life experience with few counterparts in civilian life. Upon entry into the service, individuals are assimilated into a unique institution with its own cultural and behavioral norms. A significant proportion of veterans constitute a medically complex and vulnerable health population due to the health risks that they took in service of their country. While military recruits and servicemembers are healthier than nonveterans due to medical screening requirements and fitness standards, many veterans, become insufficiently active and develop health problems soon after discharge from the military.

Haibach et al., 2016.

There are 2.1 million current military servicemembers and 21 million living veterans in the United States. Although they were healthier upon entering military service compared to the general U.S. population, in the longer term veterans tend to be of equivalent or worse health than civilians. One primary explanation for the veterans' health disparity is poorer health behaviors during or after military service, especially areas of physical activity, nutrition, tobacco, and alcohol. In response, the Department of Defense and Department of Veterans Affairs continue to develop, evaluate, and improve health promotion programs and healthcare services for military and veteran health behavior in an integrated approach.

Hoerster et al., 2012.

This purpose of this study was to compare veteran, military, and civilian men on leading U.S. health indicators. The authors collected data from the 2010 Behavioral Risk Factor Surveillance Survey, a U.S. population-based study. Despite better healthcare access, veterans had poorer health and functioning than civilians and National Guard/Reserve members on several indicators. Veterans also were more likely than those on active duty to report diabetes. Veterans were more likely to report current smoking and heavy alcohol consumption than National Guard/Reserve members and civilian men, and lack of exercise compared to active duty men and National Guard/Reserve members.

Koepsell, Forsberg, & Littman, 2009.

These authors assessed the burden of obesity and overweight, as well as trends in weight control practices, among U.S. veterans and users of Department of Veterans Affairs (VA) health care in a large national survey. Data were combined from the 2003 and 2004 Behavioral Risk Factor Surveillance System surveys of U.S. adults, a large telephone survey conducted in all states. Roughly 24% of veterans were obese, and 48% were overweight according to their body mass indexes. Among veterans, obesity was more common among users of VA care, especially those who received all health care through the VA.

Koepsell, Littmant, & Forsberg, 2012.

Veterans comprise a large and growing segment of the US population. Results from national telephone surveys suggest higher prevalence of overweight among Veterans compared with demographically similar non-Veterans, based on self-reported height and weight. Whether Veterans were more likely than demographically similar non-Veterans to be obese or overweight depended on the adiposity measure employed. On BMI, Veterans were about equally likely to be obese, but more likely to be overweight by both self-report and by direct measurement. On waist circumference, Veterans tended to have larger values than demographically similar non-Veterans, with more Veterans in the largest two categories. But on dual-photon X-ray absorptiometry, Veterans were less likely to have 35% or more body fat than non-Veterans of similar age, gender, and race/ethnicity. Life-course trends in self-reported BMI suggested a possible burst of weight gain after military discharge. These results suggest that Veterans may, on average, have less excess body fat than non-Veterans, a pattern not revealed by standard anthropometric measures.

Lehavot et al., 2012.

Women who have served in the military are a rapidly growing population. The purpose of this investigation was to estimates of several leading U.S. health indicators by military service status among women. The authors obtained data from the 2010 Behavioral Risk Factor Surveillance Survey, a U.S. population-based study. Veterans reported poorer general health and greater incidence of health risk behaviors, mental health conditions, and chronic health conditions than civilian women. Active duty women reported better access to health care, better physical health, and less engagement in health risk behaviors.

Littman, Forsberg, & Koepsell, 2009.

The purpose of this study was to describe and compare the prevalence of physical activity (PA) in relation to veteran status and use of Department of Veterans Affairs (VA) facilities. Data were obtained from the 2003 Behavioral Risk Factor Surveillance System surveys of US adults. The prevalence of inactivity was significantly lower, and meeting PA recommendations was significantly greater in veterans than in nonveterans. Despite the high level of PA required of active duty military personnel, only a minority of veterans met PA recommendations, and the prevalence of inactivity was particularly high in VA users. These findings suggest a large potential to increase PA and improve health in VA users.

Littman, Forsberg, & Boyko, 2013.

Military veterans provide a large and diverse population to examine the extent to which compulsory physical activity (PA) in early adulthood is associated with PA later in life. These authors assessed self-reported and objectively measured PA and sedentary time with valid data from the 2003–2006 National Health and Nutrition Examination Surveys. Veterans were no more likely than nonveterans to meet PA Guidelines, but may have been more likely to perform vigorous activities and conversely, to spend more time in sedentary activities.

Rosenberger et al., 2011.

The purpose of this study was to determine BMI trajectories in Iraq/Afghanistan veterans over 6 years and to examine sociodemographic factors associated with BMI trajectory membership. Higher post-deployment BMI was associated with greater BMI gain over time for both male and female veterans. Older age is associated with higher BMI regardless of gender. Education level and racial status are differentially related to BMI trajectory by gender.

Thompson et al., 2014.

The purpose of this study was to examine the effects of an acute bout of eccentric exercise on maximal isokinetic concentric peak torque of the leg flexors and extensors and hamstrings-to-quadriceps (H:Q) strength ratio. Volunteers performed maximal, concentric isokinetic leg extension and flexion muscle actions at $60°\cdot s^{-1}$ before and after (24-72 h) a bout of eccentric exercise. The eccentric exercise protocol consisted of 4 sets of 10 repetitions for the leg press, leg extension, and leg curl exercises at 120% of the concentric one repetition maximum (1-RM). The results indicated that the acute eccentric exercise protocol resulted in a significant decrease in isokinetic leg flexion and leg extension peak torque, 24-72 h post-exercise. However, the H:Q ratios were unaltered by the eccentric exercise protocol. The authors suggested that an acute bout of eccentric exercise utilizing both multi- and single- joint dynamic constant external resistance (DCER) exercises results in similar decreases in maximal isokinetic strength of the leg flexors and extensors but does not alter the H:Q ratio.

Thompson et al., 2013.

The aim of this study was to examine the effects of aging on maximal and rapid velocity characteristics of the leg extensor muscles. Participants performed three leg extension MVCs at $240°\cdot s^{-1}$ and at Vmax. Vmax was calculated as the highest velocity attained during the unloaded MVC and RVD was the linear slope of the velocity-time curve for the contractions. The old men exhibited lower Vmax and RVD values compared to the young men. These lower velocity characteristics for the old men may be attributed to the increased functional limitations often observed in older adults. Further, the present study found that the greater age-related declines for RVD values compared to Vmax, and that this could suggest an enhanced age-related impairment in the ability of the older adults' muscle to generate velocity rapidly versus the ability to generate maximal velocity. The authors suggest these findings highlight the importance of time-dependent velocity measures when assessing the effects of aging on rapid velocity capacities.

Thompson, et al., 2011.

The purpose of this study was to examine the age-related differences in maximal and rapid torque characteristics of the leg extensor and flexor muscle groups in young, middle-aged, and old men. Participants performed MVCs of the leg extensors and flexors. PT was greater in the young and middle-aged when compared to the old men for both muscle groups. Significant decreases in PT in the old men may be largely a function of mechanisms associated with loss of muscle strength and muscle mass.

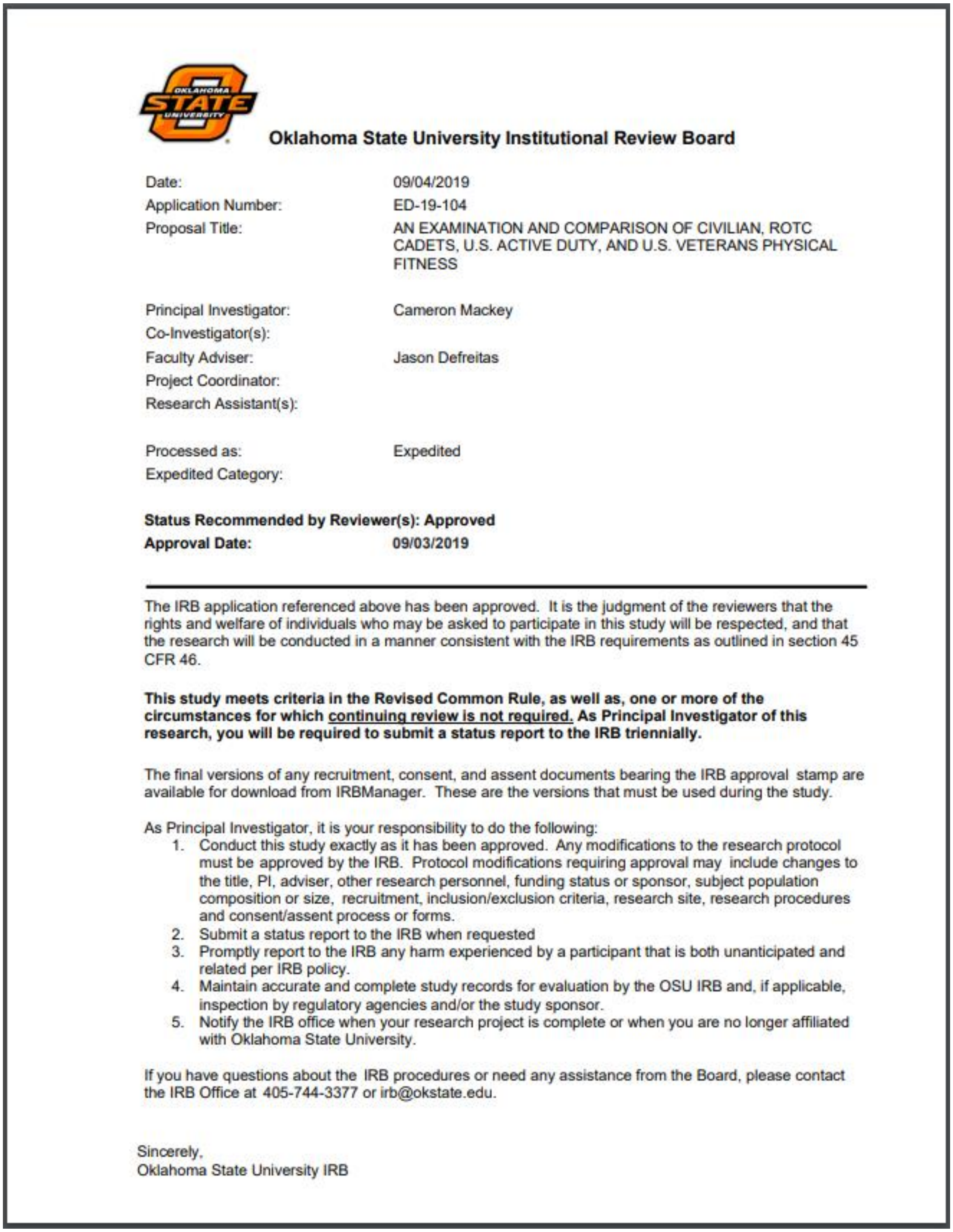
Thorstensson & Karlsson, 1976.

This study was performed to examine the development of fatigue in human skeletal muscle with repeated fast maximal isokinetic contractions, and its relation to fiber composition of the contracting muscle. The fatigability of the quadriceps muscle was investigated in 10 male subjects. Fatigability was assessed as the decline in maximal force (% of initial values) with 50 repeated isokinetic knee-extensions at fast angular velocity (3.14 radis$\cdot s^{-1}$ or180 deg$\cdot s^{-1}$). Every subject was tested on two occasions and the standard deviation for a single determination of fatigability was 1.4%. The decline in force after 50 contractions was on the average about 45%. The individual values varied, however, and a linear correlation was present between fatigability and % FT fibers. The authors concluded that development of fatigue in human skeletal muscle performing repeated fast dynamic contractions with maximal effort was most marked in muscles with a higher proportion FT fiber.

Yoon et al., 2013.

This study determined whether age-related mechanisms can increase fatigue of arm muscles during dynamic MVCs, as it occurs in the lower limb. These authors compared EF fatigue of young and old men during and in recovery from a dynamic and an isometric postural fatiguing task. Each task was maintained until failure while supporting a load equivalent to 20% of MVC torque. Transcranial magnetic stimulation (TMS) was used to assess supraspinal fatigue (superimposed twitch, SIT) and muscle relaxation. Observations for this study showed that it took longer for old men to fatigue compared to younger men for isometric contractions, however no differences were observed for dynamic contractions. Initial peak rate of relaxation was slower for the old compared to the young men and was associated with a longer time to failure for both tasks. Low initial power during EF was associated with the greatest reduction in time to failure between the isometric task and the dynamic task. SIT declined after both fatigue tasks similarly with age, although the recovery of SIT was associated with MVC recovery for the old (both sessions) but not for the young men. Biceps brachii and brachioradialis EMG activity (% MVC) of the old men were greater than that of the young men during the dynamic fatiguing task but were similar during the isometric task. Muscular mechanisms and greater relative muscle activity explain the greater fatigue during the dynamic task for the old men compared with the young men in the EF muscles. Recovery of MVC torque however relies more on the recovery of supraspinal fatigue among the old men than among the young men.

C. IRB APPROVAL LETTER



Oklahoma State University Institutional Review Board

Date:	09/04/2019
Application Number:	ED-19-104
Proposal Title:	AN EXAMINATION AND COMPARISON OF CIVILIAN, ROTC CADETS, U.S. ACTIVE DUTY, AND U.S. VETERANS PHYSICAL FITNESS
Principal Investigator:	Cameron Mackey
Co-Investigator(s):	
Faculty Adviser:	Jason Defreitas
Project Coordinator:	
Research Assistant(s):	
Processed as:	Expedited
Expedited Category:	

Status Recommended by Reviewer(s): Approved

Approval Date: **09/03/2019**

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

This study meets criteria in the Revised Common Rule, as well as, one or more of the circumstances for which continuing review is not required. As Principal Investigator of this research, you will be required to submit a status report to the IRB triennially.

The final versions of any recruitment, consent, and assent documents bearing the IRB approval stamp are available for download from IRBManager. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be approved by the IRB. Protocol modifications requiring approval may include changes to the title, PI, adviser, other research personnel, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
2. Submit a status report to the IRB when requested
3. Promptly report to the IRB any harm experienced by a participant that is both unanticipated and related per IRB policy.
4. Maintain accurate and complete study records for evaluation by the OSU IRB and, if applicable, inspection by regulatory agencies and/or the study sponsor.
5. Notify the IRB office when your research project is complete or when you are no longer affiliated with Oklahoma State University.

If you have questions about the IRB procedures or need any assistance from the Board, please contact the IRB Office at 405-744-3377 or irb@okstate.edu.

Sincerely,
Oklahoma State University IRB

VITA

Cameron S. Mackey
Candidate for the Degree of
Doctor of Philosophy

Dissertation: INFLUENCE OF TRAINING STATUS ON HUMAN PERFORMANCE AND PHYSICAL CHARACTERISTICS AMONG CIVILIAN AND RESERVE OFFICERS' TRAINING CORPS POPULATIONS

Major Field: Health and Human Performance

Academic Qualifications

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Research:

- **Mackey, C.S.** and DeFreitas, J.M. A longitudinal analysis of the U.S. Air Force Reserve Officers' Training Corps physical fitness assessment. *Military Medical Research.* Accepted September 5, 2019.

- **Mackey, C.S.**, Thiele, R.M., Schnaiter-Brasche, J.A., Smith, D.B., Conchola, E.C. Acute recovery responses of maximal velocity and angular acceleration of the knee extensors following back squat exercise. *Isokinetics and Exercise Science*. Accepted August 12, 2018.

- **Mackey, C.S.**, Thiele, R.M, Conchola, E.C., and DeFreitas, J.M. Comparison of fatigue responses and rapid force characteristics between explosive- and traditional-resistance trained males. *European Journal of Applied Physiology*. Accepted May 5, 2018.