Differences in Repeated Jump Performance While Wearing Lower-Body Compression Garments Versus a Placebo and Self-Selected Workout Attire

by

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ABSTRACT

Background: Extreme conditioning (EC) programs, such as those by Crossfit®, and Insanity™ have increased in popularity, possibly due their perceived benefits in health and fitness. Repeated bouts of maximal intensity exercises as found in EC programs may lead to a decrease in power that may affect an individual’s ability to complete a workout. Lower body compression garments (LBCG) have the potential to delay these power decrements.

Purpose: To investigate the effects of LBCG on power decrements during repeated jumps.

Methods: Twelve EC individuals (5 males and 7 females) between the ages of 18 and 40 years old with an average age, height, and weight of 29.08 ± 2.1 years, 68.17 ± 0.7 inches, and 166.1 ± 8.0 pounds respectively, participated in this study. They performed 3 trials of 4 sets of 15-second counter movement jumps (CMJ) with 10-seconds of rest between sets, in LBCG, a placebo garment, and self-selected active wear (SSAW). The garments conditions were compared using an ANOVA, with significance set at p ≤ 0.05. Results. LBCG showed a greater conservation in power during the landing phase of the repeated jump performance. In measurements of maximal negative work participants used 268.15 ± 535.65 fewer watts in LBCG than the in placebo and 283.37 ± 358.11 fewer watts than in SSAW. During eccentric work the participants required 409.43 ± 307.45 fewer watts in the LBCG than in the placebo, and 471.5 ± 307.45 fewer watts than in the SSAW. The participants experienced a 16.1 + 1.04% smaller decrement in power during the eccentric phase in LBCG than in placebo and 4.17 + 0.41% smaller than in SSAW. When the participants wore LBCG they performed 0.18 more jumps than in placebo, and 0.34 more than in SSAW. Conclusion. The increased number of jumps performed while wearing LBCG may be attributed to a greater conservation of energy during the landing phase of the repeated jump performance test. This energy
conservation may potentially help ameliorate fatigue during the latter stages of high intensity bouts of exercise.

**Key Words:** Extreme conditioning, power capacity, power decrements, plyometric training, jumping, vertical jump, compression garments
DEDICATION

This thesis is dedicated to Cindy and Lucy Tobin.

For their endless love, support and encouragement
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CHAPTER 1
INTRODUCTION

Extreme conditioning regimes are a form of high intensity interval training (HIIT) that incorporates resistance-training exercises performed at maximal or near maximal intensities, for a specific amount of time with short periods of rest. Extreme conditioning regimes often incorporate near maximal resistance training, functional or gymnastic style movements, and high intensity plyometric exercises. These exercises are performed in long or short duration intervals at high intensities.1,2 Bergeron et al.2 consulted experts in the field, about the usage of extreme conditioning programs in the military. They reported that extreme conditioning regimes differed from the traditional training used in the military in that extreme condition regimes frequently lacked a prescribed rest period, and focus on sustained high power outputs with the aim of increasing participants power capacities. Many of the workouts are performed under time restrictions, and the participants typically compete for best time or the greatest number of rounds/repetitions in a given time period.1

The sustained high power outputs typically associated with extreme conditioning regimes may improve aerobic capacity, anaerobic power, and body composition.1-4 Smith et al.1 studied 43 crossfit athletes for a period of 10 weeks. Participants significantly improved their maximal aerobic capacity (p < 0.05) and body composition (p < 0.05), regardless of their initial training status. Harris et al.3 studied a similar extreme conditioning program with 42 college football players. After 9 weeks of training, participants showed a significant improvement in lower body strength when compared to the conventionally trained athletes, as measured by the 1RM quarter squat (p ≤ 0.05), and the 1RM midthigh pull (p < 0.05), and power as measured by vertical jump height (p ≤ 0.05).
In a study by Adams et al., the investigators compared 7 weeks of a strength-based, plyometric, or extreme conditioning program. Each program consisted of twice a week training sessions under the designated test condition and a once per week training performing skill-focused training. The participants in the study had a significantly greater increase in vertical jump height of 10.67 cm under the extreme conditioning regime (p < 0.05) as compared to a 3.30 cm increase in the strength-based training group and 3.81 cm increase in the plyometric training group.

Some of the studies that used an EC program noted some decreases in power outputs resulting from fatigue during the exercises. A high volume of training combined with high intensity exercises may also lead to a depletion of neurotransmitters, phosphocreatine, and an accumulation of hydrogen ions. Girard et al. noted that a depletion of these substrates might cause a reduction in the magnitude, and frequency of muscle cell contraction, resulting in a reduction of power outputs. Fatigue is also associated with an increase in muscle oscillation and joint movement. The inability to stabilize joints during fatiguing activities is intensified during the eccentric phase of plyometric exercises. Hester et al. found that a minimum of 2 minutes of rest between bouts of maximal power efforts was necessary to maintain repeat maximal outputs, in their study that compared varying repetition ranges of squat jumps, in previously trained males. As expected, the increasing repetitions caused the participants to experience power decrements; however, when the participants were allowed 2 minutes of rest between sets there were no significant decreases for any of the repetition ranges. The researchers suggested that 2 minutes of rest allowed the participants to restore their endogenous supplies of phosphocreatine and neurotransmitters allowing them to perform at near maximal power during each of the repetition ranges.
Compression garments (CG) are constructed of restrictive spandex or elastin type material and designed to compress or constrict the limb or region covered by the material.\textsuperscript{10,12} CG are commonly used in sports or exercise programs to improve performance and/or reduce the risk of injury.\textsuperscript{12} They were originally developed for medical rehabilitation of venous retrograde flow, edema, and joint stability.\textsuperscript{12} Sear and associates\textsuperscript{13} suggested that CG may reduce muscular soreness, improve exercise economy, increase joint stability, and decrease muscle oscillation. CG effects on joint stability and muscle oscillation were most noted during studies with a high intensity eccentric phase.\textsuperscript{13,14} In the studies that investigated joint stability and muscle oscillation an improved sustainment of power during repeated jump and sprint performance were seen with the usage of compression garments.\textsuperscript{13,14} When comparing CG to loose fitting gyms shorts, Rugg and Sternlicht\textsuperscript{15} found that participants wearing CGs jumped significantly higher than participants in gym shorts (p < 0.05) after performing a pre-fatiguing 15-minute submaximal treadmill run (60.3 ± 19.4cm versus 57.7 ± 19.6cm respectively). Their findings support the possibility of a delay in decreased power outputs when using CG during repeated maximal effort jumps.\textsuperscript{15}

Individuals who frequently train with the high volumes and heavy resistance, characterized as extreme conditioning regimes, may experience an improved capacity to sustain maximal power output from wearing CG. There is still some dispute over the usage of CG in repeated efforts for maximal strength, and repeated anaerobic efforts.\textsuperscript{14,16–19} Some researchers suggest that CG may attenuate the reduction in power during repeated bouts of maximal effort exercise;\textsuperscript{14,20–22} however, many other studies show no significant effect on power from the usage of CG.\textsuperscript{16,18,23,24} Further research on the effects of CG on power decrements will allow for an end to the controversy on the efficacy of the usage of CG during
repeated maximal lower body power outputs, such as repeated jump performance. An increase in validity of CG may result in more prevalent usage, and possibly increased performance in athletes.

**Purpose**

The purpose of this study was to investigate the effects of compression garments on sustaining power and vertical jump performance when performing maximal or near maximal repeated counter movement jumps.

**Research Question(s)**

Will compression garments delay and/or reduce the magnitude of power decrements experienced by extreme conditioned participants when performing repeated maximal counter movement jumps?

**Hypothesis**

The following hypothesis will be tested at an alpha level of \( p \leq 0.05 \):

1) The usage of compression garments will show no significant benefit in the reduction of the magnitude of power decrements experienced by participants while performing a 15-second repeat counter movement jump test.

2) Wearing compression garments will not show a significantly longer delay in power decrements during or between the 15-second series of repeated counter movement jumps as compared to the repeated jump performance in non-compressive garments.

**Delimitations**

The investigators of this study set the following delimitations.
1) Twelve apparently healthy participants (5 male and 7 female) between the ages of 18-40 years old will be selected to be participants in this study.

2) Participants will have participated an extreme conditioning exercise routine at least twice a week for more than three months prior to participation in the study.

3) Subject will refrain from lower-body exercise/activities that may cause muscle soreness for at least 48 hours prior to each of the testing sessions.

**Limitations**

The limitations of this study are the restrictions of the population sampled, data collection capabilities, and accuracy of the equipment and equations. These limitations reflect the effects of the delimitations on the populations and data collection.

1) A convenience sample will be utilized, thus participants will not be randomly sampled.

2) Participants may vary from competitive athletes to recreational athletes.

3) The information from the surveys is self-reported data.

4) Diet and nutritional practices of participants will not be controlled beyond requesting participants to eat a similar diet 24 hours prior to each testing session.

5) Participants will not be screened for use of any performance enhancing substances.

**Assumptions**

The following assumptions will be made when analyzing the results of the study:

1) Participants will provide honest information in the questionnaire.

2) Participants will exert maximal effort during all testing periods and throughout the entirety of the repeat jump protocol.
3) All participants will refrain from performing significantly fatiguing lower-body exercises within the 48 hours prior to the testing periods.
Key Definitions

• Peak Power is a measurement of power output at its maximal point\textsuperscript{25}

• Average power is an average of the power output over the duration of an exercise\textsuperscript{25}

• Instantaneous power is a measurement of power output at a single moment in time\textsuperscript{25}

• Power Decrement\textsuperscript{s} are incremental decreases in power output during the prolonged performance of exercise\textsuperscript{25}

• Power capacity is the overall magnitude of power decrements during the execution of an exercise\textsuperscript{25}

• Extreme Conditioning Regimes (EC) are programs for exercise that incorporate near maximal resistance training, gymnastic, and plyometric exercises, at high intensity and intervals. These regimes frequently use HIIT protocols\textsuperscript{1,2}

• High Intensity Interval Training (HIIT) emphasizes maximal exertion for short periods of time. Often times this training style incorporates short rest periods and high volumes\textsuperscript{26}

• Compression Garments (CG) are made of material that provides an elastic resistance to compress the tissue in the limb or body region covered\textsuperscript{12}

• Lower Body Compression Garments (LBCG) cover the lower region of the body. Typically from the superior aspect of the iliac crest to the medial malleolus\textsuperscript{12}

• Bosco jump protocol is when the participants perform repeated counter movement jumps at maximal effort on a force plate or jump platform for one minute.\textsuperscript{27} Frequently used to measure power output.\textsuperscript{27}
CHAPTER 2

REVIEW OF LITERATURE

The primary purpose of this literature review is to investigate the current research related to the impact compression garments (CG) have on power decrements during repeated jump performance. Recreational athletes who train using extreme conditioning (EC) programs frequently perform high volumes of power-focused exercises with little to no rest between sets. The athlete’s ability to produce and maintain power may significantly decline throughout the duration of a maximal intensity exercise. Some evidence suggests that CG’s may potentially delay, or reduce, decrements in power during repeated bouts of maximal, or near maximal exertion. Continued research is needed to find the effects CG may have on sustaining maximal intensity jump performance.

**Anaerobic Power**

The ability to produce and sustain anaerobic power may be predictive of an athlete’s ability to stave off fatigue over the duration of a training session or competition. Without adequate rest, an athlete may experience decreases in power production and performance. Recreational and professional athletes may choose to follow an EC program, that involves short rest period between exercises in a effort to maximize their power capacity. Power capacity describes the magnitude of power decrements experienced during an activity. Power capacity is assessed by subtracting the lowest power output from the peak power output.

Frequently power capacity is increased through EC regimes, plyometric training programs, and periodized resistance training programs. When designing periodized
resistance training programs, coaches tend to focus on either improving peak power or power capacity. However, many EC regimes attempt to train power capacity and peak power output simultaneously. These regimes often use high volumes of power exercises, such as the countermovement jump (CMJ) in conjunction with high volumes of sets and repetitions. Long durations of these power exercises may cause athletes to experience power decrements during their performance. These power decrements may be the result of a reduction in motor unit activation, limitation of metabolites necessary for energy, and/or accumulation of metabolites in the muscle.

**Power Defined.** Muscular power may be defined as the rate of work produced. This can be determined by the force of the muscle and velocity of its shortening. External power may be calculated as a measurement of the force produced by the body over time. Power may be measured at different time periods during an athlete’s performance. Peak power is the measurement of the maximal power output achieved during the course of an exercise. Instantaneous power is the measurement of the power output at any singular moment in time. Average power is an average of all power outputs during repeated efforts of an exercise. Power decrements are defined as the decreases in power that often occurs during repeat performance exercise, typically caused by fatigue. Power decrements may be measured as the total difference in performance, or as the rate or magnitude of change between repeated efforts. The magnitude of power decrements is often described as the power capacity of an individual.

**Power Decrements.** In a review of the literature, Girard et al. calculated power decrements as a percentage of fatigue. Overall power decrements can be calculated by:

\[
TPD = 100 \times \left( \frac{S_{\text{best}} - S_{\text{worse}}}{S_{\text{best}}} \right)
\]
Where TPD = total power decrement, $S_{\text{best}}$ = best performance score, $S_{\text{worst}}$ = worst performance score.

To calculate the percent decrease between performances, Girard used the following calculation\textsuperscript{7}:

$$S_{\text{dec}}(\%) = \left\{ \frac{(S_1 + S_2 + \text{etc})}{S_{\text{best}} \times \text{number of repetitions}} \right\} \times 100$$

With $S_{\text{dec}}$ = the percent decrease in power, $S_1$ = the performance score of each repetition.

According to Mendez-Villanueva et al.\textsuperscript{26}, power decrements that occur during repeated maximal efforts of an exercise, such as the CMJ, may be caused by a reduction in motor unit activation, limitation of metabolites necessary for energy, and/or accumulation of metabolites in the muscle.\textsuperscript{26} Girard et al.\textsuperscript{7} suggested that the depletion of sodium ($\text{Na}^+$) and potassium ($\text{K}^+$) in the skeletal muscle after repeated maximal sprints may have contributed to power decrements during the sprints.\textsuperscript{7,7} $\text{NA}^+$ and $\text{K}^+$ are neurotransmitters that are the catalyst in exciting the muscle fibers to contract during exercise.\textsuperscript{7,26} Therefore, a decrease in these neurotransmitters may result in decreased muscle activation and contribute to power decrements.\textsuperscript{7,26} ATP supplies muscles with the energy required to generate movement.\textsuperscript{7,26,36}

After a single jump, the muscle’s supply of ATP decreases by 35%.\textsuperscript{7} A minimum of 5 minutes is needed to completely regenerate the muscle’s ATP stores.\textsuperscript{7} Without adequate rest, the inability to restore ATP to the muscle cells may lead to a reduced ability to contract the muscle. The gradual reduction in power typically seen after repetitive maximal efforts may be the result of a depletion of neurotransmitters, needed to excite the muscle cell to contract, and energy (ATP) needed to contract the muscle.

**Power Testing.** There are various laboratory and field tests that can be used as indicators of an individual’s peak anaerobic power. The simplest of these tests is the vertical
jump. Other tests such as the Wingate maximal anaerobic capacity and peak power test, Margaria-Kalaman stair climb test, and Bosco jump test may involve expensive equipment or complicated protocols.

Manning et al. found that the various anaerobic power tests provided results that were specific to the skills being tested. For instance, the power outputs for sprints may reflect the athlete’s maximal capabilities in sprinting, but they may not accurately reflect the athletes power capabilities during maximal jumps. Therefore, Manning et al suggests that there may not be a single test that measures an individual’s anaerobic power. The testing data and conclusions found in a research study may not be representative of another if the studies used different protocols to measure power.

The Bosco test may be used to predict an athlete’s power capacity. In the study by Bosco et al. the jump protocol used required the athletes to jump for one minute repeatedly on a jump mat. Bosco et al. analyzed the participants jumps for direct and indirect measurements of power. However, the continuous nature of the Bosco test may underestimate an athletes peak anaerobic power, especially in the context of intermittent sport-specific movements. A test that is performed in a more intermittent nature may allow for greater inferences regarding the range of an individual’s power capacity. Hespanhol et al. used a modified Bosco test where the participants performed 4 series of 15-second jumps with 10-seconds of rest between each series, instead of the continuous jumping for a minute. Hespanhol and colleagues found an inter-test reliability with the Bosco test in predictions of mean power and fatigue index.

Compression Garments.
CG are a clothing made of an elastic resistance material designed to compress tissue in the limb or body region covered. They were originally developed for medical rehabilitation to improve venous retrograde flow, edema, and joint stability. Some researchers theorize that CG may be worn during sports performance to decrease the extent of exercise induced muscular damage and reduce recovery time. Sear et al. suggested that wearing CG might help reduce muscular soreness and increase athletic performance by improving exercise economy. Wearing CG may also be associated with increase joint stability and decrease muscle oscillation.

Research on Compression Garments. Studies investigating the effects of wearing CG in relation to performance related markers have had equivocal results. Some studies investigating CG have found positive results in decreased muscle acidity, increased oxidative capacity, increased muscle activation, increased muscle oscillation, and improved muscle-fiber-recruitment strategies. However, these results are in contention as other studies that have found no significant difference in the aforementioned markers (p < 0.05) between wearing CG and non-compressive garments.

A factor that may account for the differences in results found between research studies is that the studies use a range of compressive forces. The compressive force within garments may range from 2mmHg up to 64mmHg. Garments that provide less compression may not be as supportive as the higher grade CG, which may result in greater muscle oscillation and a reductions in proprioception. Regardless of whether the studies found physiological evidence to support a benefit of wearing CG, the majority of studies support the finding that wearing CG elicited a perceived easing in the level of exertion, as well as a reduction in perceived muscle soreness and recovery.
Compression Garments effect on jump performance. An improvement in participants power, strength, and recovery during repeated jump-related tasks has been associated with the usage of CG.$^{15,39,46,51}$ However, there is minimal support in the literature to suggest that CG significantly affect maximal jump height.$^{15,28,39,41}$ Kraemer et al.$^{39}$ found in a study of 36 volleyball players, that wearing CG was associated with an enhanced mean power output in repeat jump performance. Their study compared repeat jump performance in participants while they were wearing compressive or non-compressive shorts using 10 maximal effort CMJs. Kraemer et al.$^{39}$ reported that the CG did not appear to significantly affect the athletes’ maximal jump height ($p > 0.05$); however, the athletes maintained a significantly higher average force output when they wore CG compared to control conditions (2,047 ± 50N in CG, vs 1,951 ± 45N respectively). They concluded that the enhanced mean force seen when wearing CG may be due to improved muscular circulation, proprioception, or reduced muscle oscillation allowing for greater muscle activation during the exercise.$^{39}$

In addition to enhanced mean force outputs some studies have found a greater maintenance in power when participants wore CGs.$^{15,51}$ Jakeman et al.$^{51}$ recruited 17 active adults to wear CG to perform vertical jumps after a pre-fatiguing plyometric exercises. After the one-hour training session the participants performed 3 squat jumps. The participants reported diminished soreness when they wore CG during the repeated squat jumps. The participants performed the pre-fatigued squat jumps at 95.2 ± 2.9% of their maximal jump height when they wore CG. In contrast, when they wore gym shorts, they performed at 88.1 ± 1.5% of their maximal jump height ($p < 0.05$). Based on these results, Jakeman et al.$^{51}$ concluded that wearing CG may decrease the amount of muscular breakdown experienced during fatiguing high intensity exercises. Similar results were noticed the study by Rugg and
Strenlicht\textsuperscript{15} who tested 14 competitive runners by having them perform a pre-fatiguing high intensity 15 minute treadmill run, followed by 3 repeat counter movement jump. Rugg and Strenlicht\textsuperscript{15} found that when their participants wore gradual CG there was a significant increase (p< 0.05) in the average vertical jump height of 2.6cm. When the participants wore gym shorts their average vertical jump height did not increase. Participants also reported decreased levels of exertion and increased levels of comfort when they wore the CG verses when they wore the gym shorts.

The study by Doan et al\textsuperscript{41} used video analysis to determine the mechanism for the improved repeated jump performance in CG found in previous studies. Doan et al\textsuperscript{41} studied 20 track athletes (10 male and 10 female) peak power production in a 60m sprint and maximal jump test. Participants were videotaped to assess joint stability and muscle oscillation during the jump test. Doan and colleagues found that participants jumped significantly higher by 2.4 cm while wearing CG when compared to the control conditions (p < 0.05). Visual assessment revealed a significant decrease in longitudinal and sagittal thigh musculature oscillation during jump landing when the participants wore compression garments (p = 0.013). The authors concluded that the decreased muscle oscillation contributed to an improved exercise economy and a greater jump height. This study provides support for the theory that participants wearing CG are likely to show an increase in power production or jump height during counter movement jump.\textsuperscript{15,39,41,46,51}

\textit{Extreme Conditioning.}

Extreme conditioning (EC) is frequently used within several popular training programs, such as the P90X\textsuperscript{TM}, Crossfit\textsuperscript{®}, Insanity\textsuperscript{TM}, and Gym Jones\textsuperscript{TM}.\textsuperscript{1,2} The EC model for programming stems from high intensity interval training (HIIT).\textsuperscript{2} HIIT typically emphasizes
maximal exertion for short periods of time with short rest periods.\textsuperscript{14} Many EC programs combine maximal resistance and power training exercises with the short intervals commonly used in HIIT.\textsuperscript{1} Typically EC regimes differ from traditional training in that they lack a prescribed rest period and focus on sustaining a high power output.\textsuperscript{2} EC programs are typically designed to improve power capacity.\textsuperscript{1,2} Frequently, EC programs incorporate Olympic lifting, power lifting, plyometric exercises and gymnastics movements.\textsuperscript{1,2} These exercises are often performed at maximal intensity and speed. Participants typically compete against each other to increase their effort and reach their maximal intensity for the workout. The prescribed goal is to achieve the best time or perform as the greatest number of repetitions in the shortest time period.\textsuperscript{1}

EC programs often incorporate high volumes of explosive movements to improve an individual’s ability to sustain power under fatiguing conditions. Several research studies indicate that this method of training may improve some components of fitness, such as aerobic capacity, anaerobic power, and body composition.\textsuperscript{1–4} For instance, Smith et al.\textsuperscript{1} found that, after 10 weeks of performing an EC training program, participants experienced significant improvements in maximal aerobic capacity (43.1 ml*kg\textsuperscript{-1}*min\textsuperscript{-1} ± 1.4 to 48.95 ± 1.42 ml*kg\textsuperscript{-1}*min\textsuperscript{-1} in men and from 35.98 ± 1.6 ml*kg\textsuperscript{-1}*min\textsuperscript{-1} to 40.22 ± 1.62 ml*kg\textsuperscript{-1}*min\textsuperscript{-1} in women, p < 0.05) and body fat percentage (22.2 ± 1.3 to 18.0 ± 1.3% in men and from 26.6 ± 2.0 to 23.2 ± 2.0% in women, p < 0.05), regardless of their initial training status. Bergeron et al\textsuperscript{2} demonstrated a similar effect on health metrics in a review of EC programs in the military. Bergeron et al noted that programs that include high intensity resistance training and conditioning intervals as is typical of many EC programs, show significant reductions in body fat, increase muscle endurance, and cardiovascular capacity.
Harris et al. studied the performance effects of an EC program on 42 collegiate football players. After 9 weeks of training, participants in the EC program demonstrated a significant improvement in lower body strength and power as measured by an increase in the participant’s 1RM parallel squat from $132 \pm 7$kg to $145 \pm 8$kg, ($p < 0.05$), and vertical jump from $184 \pm 5$cm to $246 \pm 9$cm ($p < 0.05$). Harris and colleagues concluded that the use of EC regimes improves multiple marks of performance. Adams et al. arrived at a similar conclusion in their study comparing an EC program to a traditional plyometric training program. After 2 weekly training sessions for 7 weeks of strength-based, plyometric-based, or an EC-based program participants showed a significantly greater increase of 10.67cm in vertical jump height from the EC program ($p < 0.05$) than in the plyometric and strength based training programs.

The high volumes at maximal intensity characteristic of EC regimes increase the potential risk for the negative effects of fatigue during the execution of these workouts. In a study by Luebbers et al. participants underwent a 4 week high intensity training program. The participants experienced a significant decrease in their vertical jump power from $8,660.0 \pm 546.5$W pre-intervention to $8,541.6 \pm 557.4$W immediately after the study ($p < 0.05$). Lubber and colleagues suggested that prolonged exposure to high intensity training might result in significant decreases in power output. In a study of 17 professional rugby players, Thomasson and Comfort investigated the threshold for power decrements due to fatigue during squat jumps. They found that a significant decrease in power performance may occur during prolonged bouts of high intensity exercise within a workout. This suggests that athletes may experience decreased power production within a high intensity workout, as well as after prolonged exposure to multiple high intensity training sessions.
Training volumes for extreme conditioning. Several studies have sought to determine the threshold volume to optimize power outputs.\textsuperscript{30,31,54-57} De Villarreal et al.\textsuperscript{54} conducted a meta-analysis of 56 studies to investigate the optimal training volume to improve power production in athletes. They found that optimal training volumes for power production varied with an athlete’s age and training experience. However, programs for plyometric training with at least 10 weeks and 50 jumps per session were associated with the greatest improvements in power performance (p < 0.05). Campillio et al.\textsuperscript{55} found that a volume of 240 jumps per week (broken up into 2 training session with 120 jumps per training session) significantly improved peak power performance (p < 0.05) over lower volumes of training (0 jumps per week, and 111 jumps per week) in 29 untrained high school males. These studies appear to support the higher training volumes in EC regimes as a way to maximize power production in athletes.

Conclusion.

Individuals who follow an EC regime typically combine high volumes and heavy resistance training. These training conditions may produce many positive benefits in the areas of strength, power, and body composition. However, high volumes of training coupled with short rest periods have the potential to decrease power production within the training session and during subsequent sessions.\textsuperscript{6,53} The Hespanhol\textsuperscript{35} modification to the Bosco jump test may predict an individual’s threshold for peak power performance. This information may be used to structure an individual’s power training programs. Delayed power decrements may allow individuals to train beyond their predicted threshold for peak power performance. Further research is necessary to investigate the repetition range of power decrements in repeat jump performance and the potential role CG play in alleviating power decrements.
CHAPTER 3

METHODS

Participants

After approval from the University of Colorado Colorado Springs Institutional Review Board, participants were recruited via word of mouth and written advertisement from local extreme conditioning facilities. Initially, 20 participants began the study; however, only twelve individuals (5 males and 7 females) completed this study. Five participants failed to complete all of the trial conditions due to scheduling conflicts and 3 participants withdrew from the study due to non-exercise related injuries.

The inclusion criteria required that all participants were apparently healthy and had participated in an extreme conditioning exercise program, involving plyometric exercises or jump training, at least twice a week for the last three months. All of the participants were between the ages of 18-40. Furthermore, all participants reported having performed more than 30 repeated jumps in a single training session prior to the study.

Participants were excluded from the study if they had any previous or current medical conditions that prevented them from performing the required jumps at maximal intensity and/or the participants demonstrated poor technique during the pre-participation screening. Participants were required to complete all testing sessions within a 30-day period with at least 72 hours between trials and no more than 10 days between trials. The jump performance data from participants who did not complete all testing session was not included in the results of this study.

Equipment
Participants’ weight and body composition were taken using the Tanita TBF-521 Bodyfat Monitor/Scale. For all testing session, all of the participants’ jump measurements were taken on an AMTI Force and Motion’s Accupower portable force platform, measured at 50lb, 40x30x90 composite platform.

**Pre-trial protocol**

All testing sessions took place at the University of Colorado Colorado Springs strength and conditioning laboratory. Participants were asked to refrain from any lower body lifting 48 hours prior to each of their testing sessions. Participants completed a food recall log of the type and quantity of food they consumed 24 hours prior to each testing session. Participants replicated their eating patterns prior to each trial. Participants performed each of their 3 testing sessions during approximately the same time of day to ensure consistent energy and arousal levels between trials.

Prior to admittance into the study all participants were screened using the Physical Activity Readiness Questionnaire (PAR-Q) (Appendix 1) to rule out any participants with pre-existing cardiovascular conditions, or lower limb orthopedic contraindications to exercise. An exercise and medical history questionnaire (Appendix 2) regarding age, gender, previous exercise experience, and current exercise frequency was used to determine the participants capability to perform the high intensity jump tests in this study. Participants were admitted into the study if they achieved a proficient score on the Giles 2011 Movement Dynamics Athlete Development Triple Flexion – Extension Assessment (Appendix 3). The movement screening assessed the participants’ competency in the squat movement. All participants provided an informed consent form (Appendix 4).

**Anthropometric Measurements**
Anthropometric measurement of the participants’ weight, body mass index (BMI), lean body mass percentage, and body fat percentage were taken using the Tanita TBF-521 Bodyfat Monitor/Scale prior to each trial.

**Garments**

For the duration of the study, participants were tested under each of the three study conditions: lower body compression pants (LBCG), placebo pants, or self-selected active wear (SSAW). The participants wore one study garment during each testing session. Each participant tested once in each of the three testing garments, in a randomly generated order.

The CG used in this study were men’s and women's full-length sleeved pants (Men's and Women's Elite Compression Tights, by 2XU of Melbourne, Australia). The LBCG covered from the superior aspect of the participant’s iliac crest to the participant’s medial malleolus. They were composed of a 10 mm Hg PWX FLEX fabric front panel, 18-21 mm Hg PWX fabric rear panel, both made of Invista LYCRA as ascribed by the manufacturer. The pants were fit to the participants according to the manufacture’s guidelines, according to each participant’s weight and height.

The placebo garments were Reebok long leg spandex pants (Running Essentials Tights by Reebok). The pants covered the same anatomical area as the compression pants from the superior aspect of the iliac crest to the medial malleolus. The Reebok pants were comprised of 80% polyester and 12% Elastane. The Reebok pants had no reported compression. The placebo garments were fitted to the participants in accordance with the manufacture’s preferences.
For the control, trial participants wore self-selected non-compression active wear. The shorts were loose fitted cotton, spandex, or polyester. The shorts allowed for a full range of motion at the hips and knees.

**Bosco Test**

The original Bosco protocol was a one minute repeated jump test, performed on a force platform or jump mat. From the Bosco test direct and indirect measures of power and power decrements can be analyzed. A modified Bosco test was used for this study. The participants performed 4 series of 15-second repeated CMJs. Between each of the 15-second continuous CMJ series, 10 seconds of rest were provided, in accordance with the jump procedure of Hespanhol et al. To standardize the depth of the participants’ squats during the transition from one jump to the next, a band was attached to the support beams located on the squat rack at a height such that when the participants reach 90-degrees of knee flexion their buttocks touched the band. This ensured a consistent minimum depth of squat between each jump.

**Testing procedure.**

Upon first arriving at the testing laboratory, participants completed all of their pre-trial paperwork. Anthropometric measurements were taken once the participants completed all of the pre-trial requirements. The participants were then assigned to their trial garment condition and provided time to put on the specified garment.

Once participants were in their trial garment they performed a standardized 10-minute warm up. The warm up consisted of several dynamic lower body drills: 5 each leg walking leg cradles, 5 each leg quadriceps pulls, 5 each leg walking hamstring stretches, 5 each leg front/back leg swings, 5 each leg side/side leg swings, and 10 infant squats. As part of the
warm up, participants performed 2 rounds of 10 practice countermovement jumps (CMJ) at 50% of participants’ self-described level of effort.

After the warm-up the participants stepped onto the force plate. The band was adjusted to match their designated squat depth and the force plate was calibrated for their weight. The timer for the 15-seconds of CMJ started at the beginning of the participant’s first jump. For all three testing sessions the same Bosco jump protocol was used. A second timer was used for the 10-seconds of rest between 15-second jump series. Once the participant completed 4 sets of 15-second CMJ, they rested and returned their garment to complete the trial.

**Statistical Analysis**

Direct and indirect measurements of power performance were collected from the force platform using AccuPower software. The data was manually entered into a format (excel 2011) that was acceptable for SPSS (version 23) software. Descriptive statistics were used to characterize the age, weight, and gender, of the participants. Repeated measures analysis of variance (ANOVA) was utilized to compare positive (concentric) and negative (eccentric) power decrements, maximal power, average power, and indirect measurements of power between each trial. A repeated measures analysis of variance with confounders (ANCOVA) was used to analyze the data with regard to gender. Significance was accepted at $p < 0.05$. Effect size was reported as an interpretation of Cohen’s d to represent the % of the effect on the population that may be attributed to the LBCG intervention. All results were reported as mean and standard deviations.
CHAPTER 4
MANUSCRIPT

Introduction

The popularity of extreme conditioning (EC) programs, such as those by P90X™, Crossfit®, Insanity™, and Gym Jones™ has dramatically increased over the last decade.¹,² EC regimes typically incorporate near maximal resistance training, functional or gymnastic style movements, and high intensity plyometric exercises. These exercises are performed in long or short duration intervals at high intensities.¹,² Unlike traditional training programs, EC regimes frequently lack prescribed rest periods.² Often the primary goal of an EC training session is to complete the prescribed exercises in the least amount of time or to perform the greatest number of rounds/repetitions within a specified time frame.¹

EC programs often incorporate the use of explosive movements, in order to improve an individual’s ability to sustain power under fatiguing conditions. Several research studies indicate that this method of training may improve numerous health related components of fitness, such as aerobic capacity and body composition.¹–⁴ For instance, Smith et al.¹ found that after 10 weeks of performing an EC training program participants experienced significant improvement in maximal aerobic capacity (p < 0.05) and body composition (p < 0.05), regardless of their initial training status. Bergeron et al.² reported similar health related benefits from the use of EC programs in the military.

In addition to health related benefits, numerous studies have shown that EC programs also improve aspects of athletic performance. Harris et al.³ evaluated 42 football players and found an increase in the participants’ 1RM parallel squat (p < 0.05) and vertical jump (p < 0.05), after utilizing an EC program. Adams et al.⁵ compared 2 different training methods
(strength and plyometric) to an EC program. Each method required participants to attend training sessions twice a week. A significantly greater improvement in vertical jump height of 10.67 cm was found for the EC regime in comparison to the strength and plyometric training programs (p < 0.05).

Although EC programs show increase in power output in many studies, some studies have found that individuals may experience a decrease in power during training as a result of fatigue. Thomasson and Comfort investigated the threshold for power decrements due to fatigue during squat jumps. They found that at high levels of intensity (4 sets of 6 repetitions at 60% of 1RM back squat) a significant decrease in power performance occurred during repeated bouts (p ≤ 0.05). Leubbers et al. found a decrease in power that they attributed to long-term fatigue. Participants showed significant decreases in vertical jump height and vertical jump power immediately after two weeks of a plyometric focused EC program as compared to a lower volume, lower intensity 7 week plyometric training program (p < 0.05). A similar outcome was observed when Mendez-Villanueva et al. tested 8 male cyclists’ vastus lateralis for markers of fatigue after repeated maximal power tests. The authors suggest that fatigue-related power decrements may be due to a depletion in neurotransmitters and phosphocreatine stores, which causes a reduction in motor unit activation or decreased energy in the muscle. From these studies, it may be suggested that athletes may experience decreased power production with a high intensity workout, as well as after prolonged exposure to multiple high intensity training sessions.

**Lower Body Compression Garments.** Compression garments (CG) have shown benefits in promoting blood flow, skin temperature, joint awareness, muscle vibration, and proprioception. LBCG have been used for a variety of reasons from the medical treatment
of vascular/lymphatic conditions to improving athletic performance.\textsuperscript{59} LBCG are commonly used in sports or exercise programs to reduce the effects of fatigue on performance.\textsuperscript{12} Some researchers have found that wearing LBCG improved exercise economy, by increasing joint stability and decreasing muscle oscillation.\textsuperscript{13,14,46} These physiological and biomechanical improvements may account for the reduced effects of fatigue that many studies have found with LBCG, during repeated high intensity athletic performance. \textsuperscript{15,41,51,52} Sear and associates\textsuperscript{13} suggested from their study that LBCG may improve exercise economy, increase joint stability, and decreasing muscle oscillation. LBCG effects on joint stability and muscle oscillation were most noted during studies with a high intensity eccentric phase of the exercise.\textsuperscript{13,14} In the studies that investigated joint stability and muscle oscillation an improved sustainment of power during repeated jump and sprint performance were seen when utilizing CG.\textsuperscript{13,14} When comparing CG to loose fitting gym shorts, Rugg and Sternlicht\textsuperscript{15} found that participants wearing CG jumped significantly higher than participants in gym shorts after performing a pre-fatiguing 15 minute submaximal treadmill run (60.3 ± 19.4cm versus 57.7 ± 19.6cm respectively \( p < 0.05 \)). Their findings support the possibility of a delay in decreased power outputs when using CG during repeated maximal effort jumps.\textsuperscript{15}

Although many athletes have adopted the use of LBCG to assist them in reaching and sustaining peak performance, the research is not conclusive as to the benefits of that LBCG may have on on performance. Many of the studies on LBCG report no improvements in power production with the usage of LBCG.\textsuperscript{16,18,23} Some of the conflicts within the research may be due to variations in amount of compression in the LBCG.\textsuperscript{14,59} LBCG may fit individuals differently based on their anthropometric measurements, thus each participant may experience a different magnitude of compression while wearing the garments. Some
researchers suggest that the variations in compressive forces due to difference in anthropometric measurements may result in inconsistent effects on participant’s performance.

EC athletes who are striving to maintain their peak performance for large durations of time may benefit from the influences of LBCG. The purpose of this study was to investigate the effects of LBCG on sustaining power outputs during repeated maximal effort countermovement jumps (CMJ).

**Methods**

**Participants.** Once the study was approved by the University’s Institutional Review Board (IRB) participants were recruited via word of mouth and written advertisement at local extreme conditioning facilities. Twelve (5 male and 7 female) recreationally trained EC athletes (29.08 ± 2.1 years, 166.1 ± 8.0 kg, 68.17 ± 0.7 cm) completed the study, with five withdrawing due to non-exercise related injuries or the inability to complete all testing sessions. Participants were healthy and without injury according to a Physical Activity Readiness Questionnaire (PAR-Q) assessment and medical and exercise history questionnaire. All participants performed at a proficient level on the Triple Flexion – Extension Assessment and ranged from 3 months to 5 years of previous EC program experience that included plyometrics exercises.

**Procedures.** Participants were tested under each of the three study conditions: lower body compression pants (LBCG), placebo garment, and self-selected active wear (SSAW). The participants wore one study garment during each testing session. Each participant tested once in the each of the 3 testing garments, in a randomly generated order. Participants served as their own control for comparison throughout this study. Prior to the first trial, participants
completed an informed consent waiver and food log in addition to the aforementioned medical history and PAR-Q questionnaires. At the beginning of each trial, participants completed a 24 hour food recall, and had their body weight and composition assessed using the Tanita TBF-521 Bodyfat Monitor/Scale.

*Warm up.* The pre-trial warm up consisted of 10 bilateral repetitions of walking leg cradles, quad stretches, hamstring stretches, leg swings and 10 repetitions of infant squats. Participants were also instructed with the modified Bosco\textsuperscript{17} jump protocol and performed 2 sets of 10 CMJ at 50\% of their self-described level of effort.

*CMJ.* Following the modified Bosco test,\textsuperscript{27} participants performed a jump sequence\textsuperscript{24} with 4 series of 15 second CMJs and 10 seconds of rest between series on a force platform (FP) (Accupower, AMTI Force and Motion; SR=200hz). The FP was calibrated to the participant’s weight prior to initiating the jump sequence and a timer was utilized for monitoring jumps and rest durations. Participants were instructed to perform at their maximal level of intensity for each repetition. To standardize the depth of the participants’ squats during the transition from one jump to the next, a band was attached to the support beams located on the squat rack. The band was positioned at a height such that when the participants reached 90-degrees of knee flexion their buttocks touched the band. (picture1).
**Picture 1.** Force Plate and Squat Band Set-up

![Image of Force Plate and Squat Band Set-up](image)

**Garments.** The LBCG (Elite Compression Tights; 2XU, Melbourne, Australia) were composed of a 10 mm Hg PWX FLEX fabric front panel, 18-21 mm Hg PWX fabric rear panel, both made of Invista LYCRA (picture 2).

**Picture 2.** 2XU Elite Compression Tights

![Image of 2XU Elite Compression Tights](image)

LBCG were fitted according to the manufacturer’s guidelines, covering participants from the iliac crest to the medial malleolus. Reebok long leg spandex pants (Running Essentials Tights
by Reebok) were used as the placebo garment (picture 3), fitted in accordance with the manufacture’s guidelines and covered the same anatomical area as the LBCG.

**Picture 3.** Reebok Running Essential Tights

The Reebok pants were comprised of 80% polyester and 12% Elastane, and had no reported compression. The control garments were self-selected non-compression active wear (SSAW). The SSAW were loose fitted, made of cotton, spandex, or polyester and allowed for a full range of motion at the hips and knees.

**Data Analysis.** Direct and indirect measurements of power performance were collected from the FP using AccuPower software. The data was manually entered into a format (excel 2011) that was acceptable for SPSS (version 23) software. Descriptive statistics were used to characterize the age, weight, and gender of participants. Repeated measures analysis of variance (ANOVA) were utilized to compare jump power decrements, maximal power, average power, and measurements of jump height and repetitions between using CG and not using CG. Significance was accepted at $p < 0.05$. Effect size was reported as an interpretation of Cohen’s d to represent the percent of effect that the results of this study may
have on the population that may be attributed to the LBCG intervention. All results were reported as mean and standard deviations.

**Results**

LBCG did not show a trend for greater power performance during the take off phase of the repeated CMJ performance. (Table 1). There was no significant difference between the compressive and non-compressive garments during the concentric phase of the CMJ. Separating the jump performance data by gender did not reveal any significant difference between the garments in concentric jump power. In the measurement of max force, the difference between compressive and non-compressive garments was not significant across the study $F(1,10) = 1.74 \ p = 0.217$. There was no significant difference in max force between the garments in either of the genders $F(1,6) = 1.11 \ p = 1.00$ females, and $fF(1, 4) = 0.88 \ p = 1.00$ and males. For the measurements of max power the difference between the compressive and non-compressive garments was not significant $F(1,10) = 0.002 \ p = 0.392$. There was no significant difference in max power between the garments in either of the genders $FF(1,6) = 0.458 \ p = 1.00$ females, or $F(1,4) = 0.407 \ p = 1.00$ males. The difference between garments in average peak power was not significant $F(1,10) = 0.385 \ p = 1.00$. There was also no significant difference in average power between the garments in either of the genders $F(1,6) = 1.017 \ p = 1.00$ females, or $F(1,4) = 0.248 \ p = 1.00$ males. For the concentric phase of the repeated jump performance the power decrements were not significantly different across the study $f (1,10) = 1.614 \ p = 0.27$, or for either of the genders $F(1,6) = 0.253 \ p = 0.633$ females, and $F(1,4) = 1.090 \ p = 1.00$ males.
Table 1. Mean ± SD of the Average Concentric Measurements of Power

<table>
<thead>
<tr>
<th></th>
<th>Max Force (lbs)</th>
<th>Max Power (W)</th>
<th>Average Peak Power (W)</th>
<th>Power Decrements (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LBCG</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>461.42 ± 131.05</td>
<td>3708.98 ± 804.01</td>
<td>26699.08 ± 648.26</td>
<td>59.08 ± 40.33</td>
</tr>
<tr>
<td>Female</td>
<td>371.29 ± 64.18</td>
<td>2755.33 ± 668.50</td>
<td>1918.94 ± 531.31</td>
<td>46.44 ± 5.34</td>
</tr>
<tr>
<td>Total</td>
<td>408.84 ± 103.18</td>
<td>3152.68 ± 848.51</td>
<td>2244.00 ± 684.22</td>
<td>51.71 ± 25.48</td>
</tr>
<tr>
<td><strong>Placebo</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>688.26 ± 446.73</td>
<td>3802.52 ± 784.91</td>
<td>2726.82 ± 695.66</td>
<td>40.90 ± 6.85</td>
</tr>
<tr>
<td>Female</td>
<td>500.7 ± 335.26</td>
<td>2771.63 ± 672.26</td>
<td>1940.21 ± 586.40</td>
<td>44.61 ± 5.87</td>
</tr>
<tr>
<td>Total</td>
<td>578.85 ± 378.42</td>
<td>3201.17 ± 867.37</td>
<td>2267.97 ± 726.37</td>
<td>43.07 ± 6.29</td>
</tr>
<tr>
<td><strong>SSAW</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>827.02 ± 793.15</td>
<td>3646.12 ± 997.56</td>
<td>2664.78 ± 743.54</td>
<td>40.38 ± 6.73</td>
</tr>
<tr>
<td>Female</td>
<td>370.73 ± 43.67</td>
<td>2641.53 ± 449.42</td>
<td>1716.17 ± 259.62</td>
<td>47.80 ± 9.18</td>
</tr>
<tr>
<td>Total</td>
<td>560.85 ± 533.86</td>
<td>3060.11 ± 860.02</td>
<td>2211.43 ± 690.22</td>
<td>44.71 ± 8.78</td>
</tr>
</tbody>
</table>

The LBCG showed a trend for a greater conservation of power, during the landing phase of the repeated jump performance. In a comparison of performance in the garments, the maximum negative power of participants was found to be 268.15 ± 535.65 fewer watts with LBCG than the placebo (F (1,10) =0.554 p=0.266), and 283.37 ± 358.11 fewer watts than the SSAW (F (1,10) = 554 p =0.589). In average negative power participants required 409.43 ± 307.45 fewer Watts (F(1,10) = 0.928 p = 0.240) in the LBCG than the placebo, and 471.5 ± 307.45) fewer Watts f (1,10) = 0.928 p = 0.071) than the SSAW. The Participants experienced 16.1 ± 1.04% less of a decrement in power when wearing the LBCG than when wearing the placebo garment (f (1,11) = 1.51 p = 0.004) and 4.17 ± 0.41% less than when wearing SSAW (f (1,11) = 1.51 p = 0.829).
Table 2. Mean ± SD of the Average Eccentric Measurements of Power

<table>
<thead>
<tr>
<th></th>
<th>Max Negative Power (W)</th>
<th>Average Negative Power (W)</th>
<th>Negative Decrement (%)</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LBCG</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>(3171.26 ± 753.92)</td>
<td>(2086.74 ± 748.52)</td>
<td>(8.24 ± 5.27)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>(2025.03 ± 349.86)</td>
<td>(1562.17 ± 532.80)</td>
<td>(27.33 ± 29.05)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>(2502.63 ± 788.56)</td>
<td>(1780.74 ± 656.92)</td>
<td>(12.51 ± 28.39)</td>
<td></td>
</tr>
<tr>
<td><strong>Placebo</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>(3653.04 ± 1327.84)</td>
<td>(2915.42 ± 1124.62)</td>
<td>(13.98 ± 9.43)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>(2167.00 ± 402.03)</td>
<td>(1672.13 ± 332.31)</td>
<td>(39.06 ± 31.73)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>(2770.78 ± 1324.21)</td>
<td>(2190.17 ± 964.37)</td>
<td>(28.61 ± 27.35)</td>
<td></td>
</tr>
<tr>
<td><strong>SSAW</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>(3746.30 ± 1321.61)</td>
<td>(2985.08 ± 1052.99)</td>
<td>(0.32 ± 9.37)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>(2073.99 ± 831.19)</td>
<td>(1728.79 ± 586.98)</td>
<td>(28.36 ± 32.86)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>(2786.00 ± 1146.67)</td>
<td>(2252.24 ± 964.37)</td>
<td>(16.68 ± 28.80)</td>
<td></td>
</tr>
</tbody>
</table>

The LBCG did not show a trend for increased jump height, during the repeated CMJ performance. (Table 3). There was no significant difference between the compressive and non-compressive garments, when jump height or number of jumps was analyzed. Separating the jump performance data by gender did not reveal any significant difference between the garment conditions in jump height or number of jumps performed. In an analysis of the average jump height, there was no significant difference found between the LBCG and non-compressive garments across the study F (1,10) = 0.631 p = 0.336. There was no significant difference between the garments when the data was separated by gender F (1,6) = 0.148 p = 1.00 among females, or F(1,4) = 0.869 p = 0.398 among males. An analysis of maximum jump height showed no significant differences between the performance of participants in compressive or non-compressive garments F (1,10) = 0.404 p = 1.00 in all of the participants, F(1,6) = 0.279 p = 1.00 in females, or F (1,4) = 1.212 p =0.333 in males. When the participants wore the LBCG they performed 0.18 more jumps than when they wore the placebo garments (F (1,10) = 0.694 p = 0.948), and 0.34 more than when wearing the SSAW (F(1,10) = 0.694 p = 0.432).
Although significant differences were not found between the garments there was a trend of improved performance with the usage of LBCG over the non-compressive garments during the eccentric portion of the CMJ. The effect from LBCG revealed that 21.3% of the conservation of eccentric maximal power, 27.4% of the conservation of average eccentric power, 38.2% of the attenuation of power decrements, and 7.7% of the improvement in the number of jumps performed may be seen in the populations and attributed to the usage of LBCG. In the LBCG condition participants demonstrated the greatest effects in eccentric power conservation in comparison to the non-compressive garments.

**Discussion**

The purpose of this study was to investigate the effects of LBCG on indicators of power performance among recreationally trained EC athletes while performing a series of repeated jumps. Although the results of this study showed no significant effect on the measurements of power output (p ≤ 0.05) while wearing LBCGs, the data showed a greater conservation of eccentric power and number of jump repetitions under the LBCG condition.
The lack of significant findings in this investigation are similar to those found by Pruscino et al\textsuperscript{19} who performed a similar test among field hockey players. The researchers found no significant differences in positive power force production, or any of the physiological markers of performance tested, CK, CRP, or blood lactate between LBCG and loose fitting active wear ($p \leq 0.05$). The researchers suggested that any perceived benefit to LBCG may be psychological. An inspection of the results from the study by Pruscino et al.\textsuperscript{19} suggested that the usage of LBCG may demonstrate an insignificant improvement in pre-fatigued CMJs performed within an hour of fatiguing events. This suggests that LBCG may have a biomechanical effect on CMJ performance; however, the effect may not be great enough to counteract the physiological effects of fatigue. Fatigue is caused in part by a depletion in neurotransmitters and energy substrates.\textsuperscript{7,26} Pruscino et al\textsuperscript{19} suggested from their study that LBCG did no effect the transport or production of energy substrates to the muscle.

Although wearing LBCG may not change the physiological effects of fatigue, there may be some mitigating effects from the compression of the muscles and joints covered by the garment.\textsuperscript{48} In a study by Goto et al.\textsuperscript{48} the researchers found that the compression of the lower limbs by LBCG may have protected participant’s muscles from secondary muscular damage caused by swelling. The LBCG may cause a casting effect which may maintain alignment of muscle fibers and reduce swelling. Therefore, in the execution of exercises with a high intensity eccentric phase, such as repeated CMJs, LBCG may attenuate some of the secondary effects caused by exercise-induced muscle damage allowing participants to perform at maximal capacity longer. This may not provide a significant increase in power capacity, due to the greater influences of fatigue.
Some of the effect of LBCG on eccentric power found in this study may be from LBCG effects on muscle oscillation and joint movement. In a video analysis of repeated jump performance, Doan et al\textsuperscript{41} found that LBCG may decrease muscle oscillation and improve joint proprioception. During the landing phase of repeated CMJ the muscle and joint movement was found to be greatest\textsuperscript{14}. Therefore, LBCG may show the greatest effect on power production during eccentric or landing phase. However, a study by Wannop et al\textsuperscript{59} found that participants showed improved positive power outputs in connection with an increased depth of squat during CMJ when wearing LBCG. Increased range of motion may be the reason for the increased the force produced at the push off of the jump phase and improved overall jump height. The squat depth of the participants in this study was standardized, which may have affected the concentric power and force outputs measured in this study. The variations in initial squat depth would not be seen between garment conditions; therefore, this study did not measure whether an increase in range of motion may have positively affected participants’ concentric power.

Although the majority of the differences found in this study were insignificant, 7% of the improvement in number of jumps performed may be attributed to the usage of LBCG. The increased number of jumps performed while wearing LBCG may be due to the increased conservation of power during the landing phase of the repeated CMJ performance. LBCG may provide athletes with a potential advantage in sustaining maximal power performance, during activities that include a high intensity eccentric phase. The exact mechanism by which LBCG may affect repeat jump performance is not fully understood. Further research should be conducted on LBCG, to understand the mechanism that may lead to improved power capacity.
**Practical Application**

LBCG may influence an individual’s power capacity during repeated bouts of maximal intensity power outputs. The effects of LBCG on power outputs may not be significant; however LBCG may provide an advantage in situations where the difference between success and failure is a single repetition.
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40


Appendix A

PAR-Q

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES NO

1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?

2. Do you feel pain in your chest when you do physical activity?

3. In the past month, have you had chest pain when you were not doing physical activity?

4. Do you lose your balance because of dizziness or do you ever lose consciousness?

5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?

6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?

7. Do you know of any other reason why you should not do physical activity?

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.

- Find out which community programs are safe and helpful for you.

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- Start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.

- Take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME __________________________________________________________________________

SIGNATURE __________________________________________________________________________

DATE ___________________________________________

SIGNATURE OF PARENT or GUARDIAN (for participants under the age of majority)

WITNESS ___________________________________________

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Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.
Appendix B
Questionnaire
MEDICAL HISTORY QUESTIONNAIRE

NAME: ________________________________________________________________

DATE OF BIRTH: ___________________ SEX: FEMALE       MALE

ADDRESS: ____________________________________________________________
________________________________________________________________________

CITY: ________________STATE: __________________ ZIP: ________________

EMERGENCY CONTACT: _____________________________________________

PHONE: (_______)______________________________________________________

Please circle "Yes" or "No" and provide additional details where requested on this form.

All information will be confidential.

1. Have you had a medical illness or injury since your last check up or sports physical? Yes No

2. Do you have an ongoing or chronic illness? Yes No

3. Are you allergic to any medication (aspirin, penicillin, sulfa, etc.)? Yes No
   (List________________________)

4. Do you have any food allergies? Yes No
   (List________________________)

5. Do you have any seasonal allergies that require medical treatment? Yes No
   (List________________________)

6. Are you allergic to insect bites or stings? Yes No
   (List________________________)

7. Do you take any over the counter medication(s)? Yes No
   (List________________________)

8. Do you take any prescribed medication on a permanent or semi-permanent basis
   Yes No
   (Steroids, birth control pills, anti-inflammatory drugs, antibiotics, etc.)?
   (List________________________)

9. Do you use an inhaler? Yes No
   (List________________________)

10. Do you take any over the counter dietary supplements (herbs, vitamins, minerals, protein)? Yes No
Appendix B
Questionnaire

(List___________________________)

11. Have you ever taken any dietary supplements or vitamins to help you gain or lose weight or improve your performance? Yes No
(List___________________________)

12. Do you ever have chest tightness? Yes No

13. Do you ever have wheezing? Yes No

14. Do you ever have itchy eyes? Yes No

15. Do you ever have itching of the nose or throat or sneezing spells? Yes No

16. Does running ever cause chest tightness or cough or wheezing or prolonged shortness of breath? Yes No

17. Have you ever had chest tightness, cough, wheezing, asthma or other chest (lung) problems, which made it difficult for you to perform in sports? Yes No

18. Have you ever missed school, work or practice because of chest tightness or cough or wheezing or prolonged shortness of breath? Yes No

19. If you have been told you have asthma, what medication(s) have you taken to treat it? (List___________________________)

20. Have you ever had a rash or hives develop during or after exercise? Yes No

21. Have you ever had a seizure? Yes No
(List medication(s)___________________)

22. Have you ever been told that you have epilepsy? Yes No
(List medication(s)___________________)

23. Do you have or have you ever been treated for diabetes? Yes No
(List medication(s)___________________)

24. Have you ever been told that you were anemic? Yes No
(When_______________________________)

25. Have you ever been told that you have sickle cell anemia? Yes No

26. Have you ever been told by a physician you have the sickle cell trait? Yes No

27. Have you ever become ill from exercising in the heat? Yes No

28. Have you ever passed out in the heat? Yes No

29. Have you ever had heat or muscle cramps? Yes No

30. Have you ever been told to give up sports because of health problem? Yes No

31. Has anyone in your family under age 50 died suddenly? Yes No
Appendix B
Questionnaire

32. Do you have or have you ever had high blood pressure? Yes No
   (List medication(s)__________________________)

33. Do you have or have you ever had high cholesterol? Yes No

34. Do you have trouble breathing or do you cough during or after activity? Yes No

35. Have you ever been dizzy during or after exercise? Yes No

36. Have you ever fainted or passed out when exercising? Yes No

37. Have you ever had chest pain during or after exercise? Yes No

38. Do you have or have you ever had racing of your heart or skipped heartbeats? Yes No

39. Do you get tired more quickly than your friends do during exercise? Yes No

40. Do you have or have you ever been told you have a heart murmur? Yes No
   (Give date(s)_______________________)

41. Do you have a heart arrhythmia? Yes No
   (List medication and dosage _________________)

42. Do you have a family history of heart disease? Yes No
   Describe ______________________________________

43. Do you have any other history of heart disease? (angina, arrhythmia, valve disease)
   Yes No
   Describe ______________________________________

44. Have you had a severe viral infection (for example myocarditis or mononucleosis)
   within the last month? Yes No

45. Do you have or have you ever had rheumatic fever? Yes No
   (Give date(s)_______________________________)

46. Do you have or have you ever had lung disease (pneumonia)? Yes No
   (Give date_______________________________)

47. Do you have or have you ever had kidney disease (infections)? Yes No
   (Give date(s)____________________________________)

48. Do you have or have you ever had liver disease (mononucleosis, hepatitis)? Yes No
   (Give date(s)____________________________________)

49. Do you or have you ever had a hernia or “rupture”? Yes No
   Has it been repaired? Yes No
Appendix B
Questionnaire

50. Do you have any current skin problems (for example, itching, rashes, acne, warts, fungus, or blisters)? Yes No

51. Have you been “knocked out,” become unconscious, or lost your memory? Yes No
   (Give date(s)____________________)

52. Have you had a concussion or other head injury? Yes No
   (Give date(s)____________________)

53. Have you ever had your head or neck x-rayed? Yes No

54. Have you stayed overnight in a hospital due to head injury? Yes No
   (Give date(s)____________________)

55. Do you have frequent or severe headaches? Yes No

56. Have you ever had a neck injury involving bones, nerves or discs that disabled you for a week or longer? Yes No
   (Type of injury_________ Dates________)

57. Have you ever had numbness or tingling in your arms, hands, legs, or feet? Yes No

58. Have you ever had a stinger, burner, or pinched nerve? Yes No

59. Have you ever injured your back? Yes No
   (Type of injury_________ Dates________)

60. Do you have back pain? Yes No
   (Circle those, which apply: seldom/occasionally/frequently/with vigorous exercise/with heavy lifting)

61. Do you want to weigh more or less than you do now? Yes No

62. Do you lose weight regularly to meet weight requirements for your sport? Yes No

63. Do you feel stressed out? Yes No

64. Have you had any other problems with pain or swelling in muscles, tendons, bones, or joints? Yes No
   If yes, circle which apply and explain. (head/neck/back/chest/shoulder/upper arm/elbow/forearm/wrist/hand/finger/hip/thigh/knee/shin/calf/ankle/foot)

65. Have you had a broken bone or fracture? R or L Yes No
   (What bone(s)_______________ Dates______________)

66. Have you had a shoulder injury that disabled you for a week or longer Yes No
   (dislocation, separation, etc.)?
   (Type of injury_______________ Dates ____________)

67. Have you ever had a shoulder surgery? R or L Yes No
   (What was done & why_____________ Dates ________)


Appendix B
Questionnaire

68. Does your shoulder routinely/occasionally dislocate (come out of place)/sublux?

69. Have you injured your knee? R or L Yes No

70. Have you been told by a doctor or athletic trainer that you injured the cartilage in your knee? R or L Yes No
   (Give date(s)____________________________________)

71. Have you been told by a doctor or athletic trainer that you injured the ligaments in your knee? R or L Yes No
   (Give date(s)____________________________________)

72. Have you ever had knee surgery? R or L Yes No
   (What was done ____________________ Dates __________)

73. Have you had a severe ankle sprain? R or L Yes No

74. Do you have a pin, screw or plate in your body? Yes No
   (Where in your body______________ Dates____________)

75. Have you been told by a doctor or athletic trainer that you injured the cartilage in your knee? R or L Yes No
   (Give date(s)____________________________________)

76. Do you use any special protective or corrective equipment or devices that are not usually used for your sport (for example, knee brace, special neck roll, foot orthotics, hearing aid)? Yes No

77. Have you had any surgery? Yes No
   (Specify and give details: ______________________________)

78. Do you have a pin, screw or plate in your body? Yes No
   (Where in your body______________ Dates____________)

79. Have you had any problems with your eyes or vision? Yes No

80. Which of the following dietary supplements have you taken during the past year?
   __Multi-vitamin/minerals  __Protein drinks or bars
   __Individual vitamin (e.g. vitamin C, etc.)  __Energy drinks or bars
   __Individual mineral (e.g. iron, calcium, etc.)  __Creatine
   __Protein powders or pills  __Amino acid pills or powders
   __Herbals (e.g. Ginseng, Echinacea, etc.)  __Others – please list

81. If you took any dietary supplements during the past year, how frequently did you take them? _Daily  _Occasionally  _Once a week  _Several times a week  _Only at specific times (travel, training, etc.)

82. Check the reasons for using dietary supplements during the past year:
   __To make up for an inadequate diet  __To lose weight  __To treat a medical condition or injury  __To have more energy  __To increase muscle mass/gain weight  __To
Appendix B
Questionnaire

enhance my performance _To prevent illness and disease _No specific reason

I hereby state that the questions on this form have been answered completely and truthfully to the best of my knowledge.

________________________________________
Signature of athlete                      Date

________________________________________
Signature of Investigator                Date
Appendix C
Movement Screening

Movement Dynamics
Athlete Development – Physical Competence Assessment Manual
(Triple Flexion – Extension Assessments, Double Leg Squat – Bodyweight – Arms Ahead)

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Desirable</th>
<th>Above Average</th>
<th>Average</th>
<th>Below Average</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double Leg Squat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

See Main 5 Scoring Points

- Bare Feet
- Athletes hold arms ahead for balance
- Athlete slowly sits back into a squat position with the thighs parallel to the floor.
- Use 3 attempts to assess.
- Athlete holds their head up, chest up, straight back, butt out.
- The athlete’s heels must stay in contact with the ground at all times.
- The athlete’s trunk must stay as upright as possible with neck aligned above toes.
- The main 5 scoring points. Executing all 5 points scores a desirable (5).
  - Depth – Thighs parallel to the floor
  - Ankle, Knee, Hip alignment (Knees don’t collapse in or feet don’t turn or collapse)
  - Equal stance on both legs (Hips don’t swing to favour one side)
  - Heels down
  - Trunk in proper alignment. Use the Wall Chart to assess or look for Trunk angle parallel to Shins
Appendix D
Informed Consent

University of Colorado
Colorado Springs (UCCS)
Consent to be a Research Subject

Title: Differences in repeated jump performance while wearing lower-body compression garments versus a placebo and regular non-compression workout attire

Principal Investigator: Liana Rose Tobin

Funding Source: Self-funded

Introduction
You are being asked to be in a research study and this form is designed to tell you everything you need to think about before you decide to consent (agree) to be in the study or not to be in the study. A member of the research team will describe this study to you and answer any questions. It is entirely your choice. If you decide to take part, you can change your mind later and withdraw from the research study. You can skip any questions that you do not wish to answer.

Before making your decision:
- Please carefully read this form or have it read to you.
- Please ask questions about anything that is not clear.

Feel free to take your time thinking about whether you would like to participate. By signing this form, you will not give up any legal rights. If you are completing this consent form online, you may want to print a copy of the consent form for your records.

Study Overview
This study plans to learn more about the differences in power production while performing repeated jump efforts while wearing a lower-body compression garment (LBCG) versus placebo garments and regular non-compression workout attire.

Procedures
- You are being asked to be in this research study because your have previous experience in training under an extreme conditioning regime. You are healthy and free of all contradictions for exercise and between the ages of 18 and 40. You have sufficient coordination as assessed by Giles Movement Dynamics Physical Competence.
- In this study, you will be asked to keep a food journal detailing all the food and drink that consumed within the 24 hours prior to their arrival at the testing location. You will be requested to repeat a similar diet prior to each of the 3 testing sessions and wear the same attire to each testing session.
- Upon arrival to the first testing session, you will have your anthropometric measurements (i.e., height, weight, and body composition) taken. You will be provided testing lower body garments and then requested to perform a standardized 10-minute warm up.
- Following the warm up, you will step onto the force platform within the squat rack and perform a bodyweight squat until your buttocks are in contact with a band that will be placed across the supports of the squat rack at the desired squat depth. You will be invited to perform up to 10 practice jumps at 50% of the your self-described level of effort. Then rest for 3 minutes before the testing session begins.
- You will then be requested to perform a modified Bosco jump protocol. You will again be asked to step into the force platform, place their hands on their hips, and squat until their thighs are parallel to the ground and their buttocks touches the band across the squat rack, and then perform a countermovement jump (CMJ). You will repeat this procedure for 15 seconds. Once this has been
completed, you will be allowed 10 seconds rest and this procedure will be repeated 3 more times. At the completion of the jump test, you will be instructed to rest until they no longer feel exerted and are comfortable.

Other people in this study
Up to 30 people will participate in this study.

Risks and Discomforts
The potential risks of the study are:
- Risk of a cardiac event as a result of repeated bouts of high intensity power efforts
- Risk of acute or chronic orthopedic injury as a result of improper landing mechanics during repeat jumps
- Risk of gastrointestinal distress as a result of blood shunting during maximal exercise exertions
- Risk of dizziness, or loss of conscience as a of a decrease in blood pressure after maximal exercise exertion
- Risk of fatigue caused by maximal exertion for a prolonged duration.
- Allergic reaction to the LYRCA in the compression and placebo garments
- Asthmatic reaction during jump performance.

Benefits
This study is designed for the researcher to learn more about the efficacy of compression garments when attempting to improve repeated jump performance. The information from this study can be used to provide additional insight into the efficacy of compression garments when seeking to improve peak and average power production, sustained power production, reducing power decrements and reducing fatigue.

Participants will receive information regarding their repeat jump performance, which would provide them with valuable insight regarding how they may want to adjust their personal workout sessions.

Compensation
There will be no monetary compensation for this study.

Confidentiality
The data retrieved from this study will be stored on the researcher's virus protected and encrypted iCloud storage. All physical paperwork will be stored at the University of Colorado Colorado Springs Strength and Conditioning laboratory, under lock and key. Identifiers of the participant’s will be excluded from all data collected and paperwork filled out. The participants will be assigned an identifier code at the pre-participant meeting and the code will be used for all paperwork, and data retrieved.

Certain offices and people other than the researchers may have access to study records. Government agencies and UCCS employees overseeing proper study conduct may look at your study records. These offices include the UCCS Institutional Review Board, and the UCCS Office of Sponsored Programs and Research Integrity. UCCS will keep any research records confidential to the extent allowed by law. A study number rather than your name will be used on study records wherever possible. Study records may be subject to disclosure pursuant to a court order, subpoena, law or regulation.

Voluntary Participation and Withdrawal from the Study
Taking part in this study is voluntary. You have the right to leave a study at any time without penalty. You may refuse to do any procedures you do not feel comfortable with, or answer any questions that you do not wish to answer. If you withdraw from the study, you may request that your research information not be used by contacting the Principal Investigator listed above and below.
Appendix D
Informed Consent

Contact Information
Contact (PI's info): Liana Rose Tobin ltobin@uccs.edu
• if you have any questions about this study or your part in it,
• if you have questions, concerns or complaints about the research, or
• if you would like information about the survey results when they are prepared.

Contact the Research Integrity Specialist at 719-255-3903 or via email at irb@uccs.edu:
• if you have questions about your rights as a research participant, or
• if you have questions, concerns or complaints about the research.

Electronic Consent
Please print a copy of this consent form for your records, if you so desire.

I have read and understand the above consent form, I certify that I am 18 years old or older and, by clicking the submit button to enter the survey, I indicate my willingness voluntarily take part in the study. «You may need to modify this sentence if the "click to continue" button is called something other than "submit."»
Appendix D
Institutional Review Board Letter of Approval

Date: 10/28/2015

Institutional Review Board (IRB) for the Protection of Human Subjects

IRB PROTOCOL NO.: 16-069
Protocol Title: Differences in repeated jump performance while wearing lower-body compression garments versus a placebo and self-selected workout attire
Principal Investigator: Liana Tobin
Faculty Advisor if Applicable: Jay Dawes
Application: New Application
Type of Review: Expedited
Risk Level: No more than Minimal Risk
Renewal Review Level (If changed from original approval) if Applicable: N/A No Change
This Protocol involves a Vulnerable Population: N/A (No Vulnerable Population)
Expires: 27 October 2016

Note, if exempt: If there are no major changes in the research, protocol does not require review on a continuing basis by the IRB. In addition, the protocol may match more than one review category not listed. Externally funded: ☒ No ☐ Yes

OSP #: Sponsor:

Thank you for submitting your Request for IRB Review. The protocol identified above has been reviewed according to the policies of this institution and the provisions of applicable federal regulations. The review category is noted above, along with the expiration date, if applicable.

Once human participant research has been approved, it is the Principal Investigator’s (PI) responsibility to report any changes in research activity related to the project:

• The PI must provide the IRB with all protocol and consent form amendments and
Appendix D
Institutional Review Board Letter of Approval

revisions. ○ The IRB must approve these changes prior to implementation.

• € All advertisements recruiting study subjects must also receive prior approval by the IRB.

• € The PI must promptly inform the IRB of all unanticipated serious adverse events, within 24 hours. All unanticipated adverse events must be reported to the IRB within 1 week (see 45CFR46.103(b)(5)). Failure to comply with these federally mandated responsibilities may result in suspension or termination of the project.

• € Renew study with the IRB prior to expiration.

• € Notify the IRB when the study is complete. If you have any questions, please contact Research Compliance Specialist in the Office of Sponsored Programs at 719-255-3903 or irb@uccs.edu. Thank you for your concern about human subject protection issues, and good luck with your research. Sincerely yours, Michele Okun, PhD