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Effects of ankle weights on metabolic response and muscle activity
on a lower body positive pressure treadmill

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Submitted in Partial Fulfillment of the
Requirements for the Master of Science in Exercise Science Degree

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May 2017

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ABSTRACT

Lower body positive pressure (LBPP) treadmills are growing in popularity for rehabilitative use, as the benefits of exercising at partially supported body weight may induce faster recovery. It is unknown if there are certain practices that increase exercise intensity while maintaining positive effects of LBPP. Adding ankle weights when walking or running could increase intensity of rehabilitation programs while maintaining the comfort of supported body weight. **PURPOSE:** To measure metabolic response (VO_2 , RER, HR, Caloric expenditure), RPE, and lower limb electromyography (EMG) amplitudes of LBPP treadmill walking and running with and without ankle weights. **METHODS:** Sixteen participants (Age: 21.94 ± 1.44 years; Height: 1.66 ± 0.15 m; Weight: 66.86 ± 18.25 kg) completed two randomly-selected, separate sessions of 4 min. walking at $1.34 \text{ m}\cdot\text{s}^{-1}$ and 4 min. running at $2.68 \text{ m}\cdot\text{s}^{-1}$ in LBPP: (a) in a no weight (NW) condition and (b) an ankle weight (AKW) condition, both at 60% body weight (40% of body weight supported). **RESULTS:** Participants' average (\pm SD) relative VO_2 was 10.37 ± 1.49 and $20.33 \pm 3.38 \text{ mlO}_2/\text{kg}/\text{min}$ for NW at the two treadmill speeds. AKW VO_2 was 12.2 ± 1.46 and $23.29 \pm 4.86 \text{ mlO}_2/\text{kg}/\text{min}$. RER for NW was $.89 \pm .064$ and $.95 \pm .063$; RER with AKW was $.87 \pm .061$ and $.96 \pm .077$. HR at the NW condition was 103.2 ± 17.3 and 140.0 ± 21.1 bpm; AKW condition HR was 99.36 ± 13.3 and 143.8 ± 20.3 bpm. Caloric expenditure at the NW condition was 14.4 ± 4.90 kcal at the fourth minute of walk and 28.1 ± 9.16 kcal after the complete eight minutes. At the AKW condition caloric expenditure was 16.8 ± 4.77 kcal at the fourth minute of walk and 31.9 ± 10.2 kcal after the complete eight minutes. For the NW condition RPE was 7 ± 1 and 9 ± 2 , and 7 ± 1 and 11 ± 1 at the AKW condition. EMG data RMS were calculated then normalized to 100% body weight and expressed as a percent. The maximum peak values from 30s recordings

were averaged to represent final EMG amplitudes. EMG of the gastrocnemius at the NW condition was 560.5 ± 181.9 for walk and $485.0 \pm 124.6\%$ for run; at the AKW condition EMG of the gastrocnemius was $586.5 \pm 237.6\%$ and $461.2 \pm 171.7\%$. EMG of the tibialis anterior at the NW condition was 570.4 ± 158.9 and $647.7 \pm 443.5\%$. At the AKW condition EMG of the tibialis anterior was 581.2 ± 363.3 and $546.9 \pm 377.2\%$. Lastly, the EMG of the vastus medialis at the NW condition was 606.7 ± 441.8 and $448.2 \pm 316.0\%$; at the AKW condition EMG of the vastus medialis was 521.8 ± 537.0 and $633.3 \pm 629.9\%$. A two-way repeated measures ANOVA indicated a statistically significant interaction of speed and weighted condition for RER, $F(1,13) = 4.834$, $p < .05$, partial $\eta^2 = .271$. RER was statistically significantly different between both speeds at both conditions. RPE was statistically significantly different at $2.68 \text{ m} \cdot \text{s}^{-1}$ between the weighted conditions, $F(1,15) = 6.505$, $p < .05$, partial $\eta^2 = .303$. The remaining variables did not have significant interactions between speed and weighted condition. **CONCLUSION:** The NW condition had slightly lower means than the AKW for metabolic and RPE data. Electromyography results did not show a large difference in muscle activity between the NW and AKW conditions. The most notable differences occurred at the running speed for the vastus medialis. It was concluded that the addition of ankle weights had a small effect on increasing metabolic response, rating of perceived exertion, and muscle activity but not enough to substantially increase exercise intensity of walking or running while in LBPP. This practice may be applied to those using the AlterG® that are not confident enough to raise body weight closer to 100%, but want to increase intensity via rating of perceived exertion.

ACKNOWLEDGEMENTS

I would like to formally thank my thesis chair, Dr. Jim Hokanson, for introducing me to the world of research. My involvement in projects with him prior to beginning the Master's program here at SUNY Cortland are what inspired me to continue and complete a thesis. I would also like to thank my committee members, Dr. Peter McGinnis and Dr. Larissa True, for their guidance, expertise, and support throughout this process. Finally I would like thank Dr. Buckenmeyer, Ms. Julie LaPlant, and Dr. Kevin Dames for their patience and assistance during the not so straightforward data collection period.

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CHAPTER 1

INTRODUCTION

Walking and running are common forms of exercise that provide positive benefits to the human body (Lee et al., 2014; Patterson et al., 2007). These basic exercises are useful for rehabilitating lower body injuries but are not always achievable immediately following an injury. Several practices have been developed to speed up recovery time in order to return to exercise faster; specialized equipment or techniques designed for these purposes can reduce ground reaction forces (GRFs) or relieve stress by partially supporting a person's body weight. Body unweighting is a relatively new technique applied to exercise to achieve rehabilitative, clinical, and training goals.

Water rehabilitation and harness systems are two methods used to create body unweighting. Low-pressure environments are simulated to reduce ground impact forces but can hinder performance when restricted by harnesses or attempting to maintain proper form underwater. These methods are commonly used for rehabilitation but a major drawback is they provide little control over what the unweighting body percentage is.

A more useful unweighting technique is lower body positive pressure (LBPP) technology. Lower body positive pressure machines enclose a person from the waist down in a chamber that is then filled with air, increasing the pressure in the chamber, supporting a percent of their body weight to make them weigh less. The design allows for an upright standing position inside, making walking and running possible. The AlterG® Treadmill uses LBPP to create specific percentages of body weight for individuals, going as low as 20% body weight (80% body weight supported). This treadmill is easy to use and accessible for a broad range of patients with various health conditions from obesity to lower limb injuries.

Since LBPP is a relatively new concept there is a lack of research on metabolic response and muscle activity when walking or running at various supported body weights. It is important to understand if performance in a LBPP device is adequate for people wishing to regain or maintain higher levels of exercise and energy expenditure during rehabilitation. Using an AlterG® Treadmill may enable a person to begin rehabilitation therapy sooner, exercising at an unweighted condition as opposed to full body weight.

Muscle activity of the lower limbs was investigated in one LBPP setting, which found most muscle amplitudes lowered as body weight decreased (Hunter, Seeley, Hopkins, Carr, & Franson, 2014). However, there has been no research on whether muscle activity can be increased in LBPP. Increasing muscle activity to regain strength could be the next step for a rehabilitation program for a patient utilizing LBPP. Adding ankle weights to the patient may be one method to increase muscle activity while rehabilitating or exercising in a LBPP condition.

Statement of the Problem

Research has been conducted investigating differences in metabolic response while walking and running in LBPP conditions (Cutuk et al., 2006). There is limited research of oxygen consumption, respiratory exchange ratios, and muscle activity together in LBPP. Few studies assess walking and running for rehabilitative practices on LBPP machines while attempting to increase muscle activity.

Muscle activity can be increased with the addition of ankle weights, however the increased ground reaction forces caused by the ankle weights may be unhealthy at full body weight. In LBPP, ground reaction forces have shown to decrease as body weight decreases

(Raffalt, Hovgaard-Hansen, & Jensen, 2013). The addition of ankle weights at LBPP has not been investigated.

Wearing external ankle weights while walking or running in LBPP may be beneficial by slightly increasing intensity to regain strength in muscles that have been sedentary due to a lower limb injury. If GRFs remain low while muscle activity increases from wearing ankle weights, a wearer may see increases in muscular strength without experiencing the negative effects of increased ground reaction forces.

Purpose of the Study

The purpose of this study was to examine the difference in metabolic response and rating of perceived exertion while walking and running at LBPP with and without ankle weights. A secondary purpose was to investigate the difference in lower extremity muscle activity while walking and running at LBPP with and without ankle weights.

Hypothesis

It was expected that walking and running with ankle weights in LBPP would significantly increase oxygen consumption, heart rate, respiratory exchange ratio values, caloric expenditure, rating of perceived exertion, and muscle activity compared to running and walking in LBPP without ankle weights.

Delimitations

The following delimitations were included in the study:

1. The ankle weights were 0.64 kg (1.4 lb.) for all participants.
2. The protocol was conducted at one lower body positive pressure condition on the AlterG® Treadmill: 60% body weight (40% of body weight was supported).
3. The protocol included one walk speed, $1.34 \text{ m}\cdot\text{s}^{-1}$ and one run speed, $2.68 \text{ m}\cdot\text{s}^{-1}$.

4. Participants were college students from the State University of New York College at Cortland, ages 18-26 years old.
5. Anyone that had suffered a lower body injury within the past 12 months at the time of recruitment was excluded.
6. Participants from all SUNY Cortland division III teams were excluded from data collection.
7. Sixteen total participants were randomly selected to complete the study.
8. There was a minimum 24-hour period in between testing sessions for each participant.

Limitations

The following limitations were included in the study:

1. Ground reaction forces could not be measured to compare ankle weight and no weight conditions.
2. The diet of participants was unknown throughout the experimentation.
3. Participants were instructed not to consume caffeine prior to testing sessions but there was no guarantee they followed those instructions.
4. Participants were instructed not to exercise at least 12 hours prior to their testing sessions but there was no guarantee they followed those instructions.
5. Differences in muscle and fat mass between participants could not be controlled for that created variability in the electromyographic analysis. Limb lengths were not recorded.
6. Gait patterns differed between participants that could not be controlled for that created variability in the electromyographic analysis.

7. There were changes in gait once the speed of the treadmill switched from $1.34 \text{ m}\cdot\text{s}^{-1}$ to $2.68 \text{ m}\cdot\text{s}^{-1}$ as the participants adjusted to running.
8. The heat inside the AlterG® Treadmill could not be accounted for as participants began run sessions; multiple sessions occurred in the same day and the treadmill was aired out in between trials for at least 10 minutes.
9. Participants did not have a practice session prior to using the treadmill for their tests.
10. One major limitation of this study was the researcher's reliance on the software programs on the metabolic cart to work properly; the Breeze software malfunctioned during the data collection process for two participants. Due to this and time constraints, metabolic data for the no weight condition could not be obtained for two participants; therefore some results only have $n = 14$ rather than $n = 16$.

Assumptions

1. When wearing ankle weights it was assumed there would be an increase in ground reaction forces on the lower body and impact while walking and running due to the increase in mass around the ankle.
2. It was assumed that participants did not consume caffeine prior to testing sessions.
3. It was assumed participants did not perform extra exercise bouts prior to testing sessions.
4. It was assumed the temperature inside the AlterG® Treadmill did not interfere with the participant's performances.

Definition of Terms

- Lower body positive pressure (LBPP): The unweighting of the lower body of an individual to a certain percentage of their original body weight; specifically in this study

it is a technique that increases air pressure around the legs to support more body weight while exercising.

- Metabolic response: The body's reaction to exercise. This study includes oxygen consumption, respiratory exchange ratio, heart rate, and caloric expenditure as the definition of metabolic response.
 - Oxygen consumption (VO_2): The amount of oxygen taken in by an individual, specifically in this study while they are walking and running, expressed in $\text{mlO}_2 \cdot \text{kg} \cdot \text{min}$.
 - Respiratory exchange ratio (RER): The ratio of carbon dioxide to oxygen a person consumes and produces while at exercise. RER typically falls between 0.6-0.8 when fat substrates are utilized for fuel. At more intense exercise levels where carbohydrates are primarily utilized, the RER values range from 0.9-1.0 or greater (Katch, McArdle, & Katch, 2011).
 - Heart rate (HR): The rate of pumping done by the heart. Resting HR values are usually 60-100 bpm, beats per minute (Katch et al., 2011).
 - Caloric expenditure: The burning of Calories during physical activity, units expressed as kcal. (American College of Sports Medicine [ACSM], 2006).
- The Borg Rating of Perceived Exertion Scale (RPE): A scale that measures the intensity of physical activity as subjectively described by the participant of exercise. The scale reads from 6-20 and can be attributed to the exerciser's heart rate and physiological responses. A rating of 12-14 is commonly considered moderate intensity.
- Electromyography (EMG): The use of surface electrodes to record electrical activity within muscles (Hamill & Knutzen, 2003).

Significance of the Study

Unweighting via the AlterG® Treadmill creates a unique and secure environment to exercise in rather than a regular treadmill. Relieving a percentage of pressure on the lower extremities via the AlterG® has been found to lower pain and increase confidence in users, allowing them to return to exercise sooner. LBPP reduces ground reaction forces while metabolic demand is maintained when walking and running (Grabowski, 2010); adding ankle weights may help strengthen muscles while maintaining low impact levels.

The theorized practical significance of this study was to apply the concept to patients and athletes in rehabilitative settings. If adding ankle weights was safe and comfortable, participants could potentially increase metabolic response and caloric expenditure walking and/or running, while at a lower percentage of full body weight. The greater amount of mass around the ankle aimed to increase muscle activity; meanwhile walking and running might have subjectively feel easier with ankle weights on at reduced body weight conditions, rather than full body weight.

This research was important because these specific questions had not been investigated before. This study could provide a basis for future investigations on incremental changes in mass while exercising at lower body positive pressure.

CHAPTER 2

REVIEW OF LITERATURE

A review of current literature on unweighting and lower body positive pressure is presented in this chapter. Physiological, respiratory, and cardiovascular responses, as well as oxygen consumption observations of walking and running in LBPP are investigated. Lower body positive pressure gait analysis walking at incremental speeds is reviewed, as well as research on ground reaction forces in LBPP. Clinical research studies utilizing lower body positive pressure are summarized. The chapter includes information on metabolic cost and physiological responses of exercising with external ankle weights. Finally there is a review of electromyography, and its use in lower body positive pressure research.

Unweighting

A process growing in popularity and interest is the practice of unweighting during exercise. Deep water running is one unweighting technique frequently used for rehabilitative processes to supplement dry land running post-injury (Assis et al., 2006). For this method, a person is partially submerged in water and a flotation vest is worn to keep their feet from touching the bottom of the pool (Kanitz et al., 2015). The vest design is popular because it eliminates impact forces. However this technique is not ideal, as normal gait kinematics cannot be recreated due to drag forces in the water (Mercer, Applequist, & Masumoto, 2014). Additionally deep water running elicits lower muscle activity than regular treadmill running when matched to RPE. In order to achieve deep water running muscle activity patterns similar to regular treadmill running, higher levels of RPE must be achieved (Masumoto, Delion, & Mercer, 2009). Increasing RPE levels too high could be strenuous and even dangerous for an individual just beginning a rehabilitation program.

Lower Body Positive Pressure (LBPP)

One concept of unweighting originated from the idea of recreating microgravity for testing exercise protocols in space. A lower body negative pressure system was created to examine physiological responses to exercising in simulated gravity. The device was one of the first to have a person standing rather than sitting, creating a bipedal low-pressure environment a person could still walk in. A seal around the waist was used to fully enclose the subject (Hargens, Whalen, Watenpaugh, Schwandt, & Krock, 1991). This concept is integrated into current equipment used for creating LBPP to study exercise and research protocols.

The AlterG® Treadmill applies LBPP to rehabilitative, clinical, and research settings. This treadmill encloses a person up to their waist in an air chamber by wearing neoprene shorts that have a zippered skirt around the waist that seals them in the chamber. Once sealed the chamber can be adjusted to any desired pressure gradient via an air compressor (Cutuk et al., 2006). Increasing the pressure inside the chamber creates the body weight support that makes the user a certain percentage of their normal body weight. The AlterG® can go down to 20% body weight all the way up to 100% body weight. Using lower body positive pressure aims to reduce stress, ground reaction forces, and overall difficulty of specific rehabilitation tasks (Cutuk et al., 2006).

Metabolic Response

Raffalt et al. (2013) measured metabolic variables of 12 healthy male runners at multiple unweighted running conditions while running at LBPP. Heart rate, blood lactate concentrations, and ventilation were measured throughout each running trial. Heart rates were observed to decrease as body weight decreased and ventilation had a proportional

decrease to body weight. Breathing rate was unaffected by body weight reduction at all speeds but increased intra-running bout as speed increased at one body weight.

Hoffman and Donaghe (2011) assessed physiological responses of walking and running in LBPP and found the relationship between heart rate and oxygen consumption was not adversely affected by partial body weight support. The LBPP environment had a minimal effect on the relationship between RPE and VO_2 , and reduced ground reaction forces were observed. A major conclusion from this study was that LBPP was feasible for training programs based on target heart rates; a similar metabolic demand could be expected from workouts in LBPP up until around 50% body weight support as unsupported exercise (Hoffman & Donaghe, 2011). An additional AlterG® study focused on oxygen consumption for elite distance runners. Oxygen consumption increased as speed increased in each condition. At lighter percentage body weights, oxygen consumption was proportionally lower than at the fully supported weight condition (McNeill, Kline, DeHeer, & Coast, 2015).

Another AlterG® study assessed maximal oxygen consumption tests for ten subjects at 100, 90, and 80% body weight. Significant differences were not found comparing VO_2 , heart rates, and RER values at all three conditions. These results may have been due to the small amount of unweighting, 80% body weight being the lowest percentage studied. Additionally, mass remained unchanged even though body weight was altered from the positive pressure (Figueroa, Manning, & Escamilla, 2011). This information contributed to the current research study creating a change in mass of the individual exercising in LBPP. The next study reviewed analyzed various supported body weight values that show metabolic and physiological responses change during running bouts.

This study observed 12 healthy experienced male runners for three 12-minute trials to reach steady state at submaximal exercise levels. Trials consisted of 10, 14, and 18 km·hr⁻¹ on the LBPP treadmill, separated by four and six minutes of rest (Raffalt et al., 2013). During the trials unweighting percentages were randomly selected out of 100, 75, 50, and 25%. Subjects were given a rest period then performed another run bout, next at higher speeds of 20 and 22 km·hr⁻¹, at the same four unweighted conditions but for 20 seconds.

During submaximal trials, VO₂ ranged between 28% and 76% of reported VO₂ max. At each reduced body weight condition there were significant decreases in VO₂ at each speed. VO₂ had a linearly significant increase as body weight increased towards full body weight. Heart rate and ventilation showed similar significant trends of decreasing as body weight decreased (Raffalt et al., 2013). This research reported that running in LBPP creates lower oxygen cost and was imperative information for the current study's protocol and method design. Using the information from these research studies contributed to determining the unweighting percentage of the proposed protocol, 60%, rather than a higher or lower value.

Gait & Ground Reaction Forces

Cutuk et al. observed cardiovascular safety and gait analysis while participants stood, walked, and ran in LBPP (2006). Gait analysis was performed to ensure participants walking on the AlterG® Treadmill could maintain a normal range of motion in the joints. Six male subjects with no gait abnormalities were tested. Chamber pressures were determined to be at 100, 60, and 20% body weight. Subjects walked at 1.34 m·s⁻¹ at each condition and data was collected after one minute of exercise to allow subjects time to acclimate to the current pressure (Cutuk et al., 2006). Post-gait analysis results found all six subjects were able to

walk comfortably at each decreased body weight condition. Running at LBPP had no significant effect on range of motion in the ankle and there were no significant changes found in knee range of motion (ROM), although there was a noted trend that knee ROM was lower while walking. A final observation was a significant increase in stride length while walking at each condition except for 100% (Cutuk et al., 2006). This research supports the notion that walking and running at different LBPP unweighted conditions does not hinder performance or adversely affect gait.

Although extensive research does not exist in this category, gait mechanics of post-knee surgery patients at LBPP conditions have been specifically assessed. One study designed to measure ground reaction force measurements had nine participants walk in LBPP conditions wearing specialized shoes to capture forces. Results found GRFs were reduced with the reduction of body weight when walking and normal gait mechanics were maintained (Eastlack et al., 2001).

Multiple research studies that focus on LBPP assess the changes in ground reaction forces when exercising at an unweighted condition. One study with 12 healthy participants running at maximal and submaximal intensities, found reducing body weight decreased vGRFs, and vGRFs were decreased more at higher speeds rather than lower (Raffalt et al., 2013). An additional study found the increase in chamber pressure inside the AlterG® reduced knee forces while walking due to reduced treadmill reaction forces (Patil et al., 2013). A fourth study found decreases in vertical impact peak GRFs and active peak GRF decreased as body weight decreased (Grabowski & Kram, 2008). This research supports walking and running in LBPP suggesting that GRFs are reduced with body weight reduction,

and do not negatively impact the user. The use of LBPP is seen as an acceptable technique to apply to gait recovery programs in physical therapy settings as well as clinical settings.

Clinical Research

A more recent study examined overweight, at-risk, knee osteoarthritis patients and their pain responses to walking in LBPP versus walking at 100% bodyweight. Twenty-two patients walked at 1.39 m·s⁻¹ for 20 minutes, and body weight support was adjusted at 5% increments, unaware to the participants. Results showed as little as 12.4% body weight supported (~88% LBPP) was the minimum requirement to reduce or diminish knee pain for the patients in the study, with 15% being the median amount of support required. (Takacs, Anderson, Leiter, MacDonald, & Peeler, 2013). This study provides useful information for the current research project; if walking with ankle weights is feasible and not debilitating to participants, wearing ankle weights may be the next step for a patient to increase strength in the lower extremities, while still feeling confident and safe in LBPP.

Lower body positive pressure has been tested in several clinical populations since its reputation as a rehabilitative tool has become better known. One LBPP rehabilitation study implemented a running protocol for patients recovering from Achilles tendon surgery. Patients began using the AlterG® week 2 post-surgery, walking at 40% bodyweight for ten minutes. For the next four weeks usage of the AlterG® increased gradually until patients could run for as long as two minutes at 85% bodyweight (Saxena & Granot, 2011). The ultimate goal was to run outside at full body weight; the AlterG® group was outside running at 18.1 ± 3.9 weeks, with the control running outside at 20.4 ± 4.1 weeks. The control group in this study had a significantly slower return to running at full body weight outside.

An eight-week intervention studying 13 patients with Parkinson's disease required them to train in LBPP. The objective was to increase exercise intensity and complexity of motor challenges during training. Clinical status, quality of life, and gait capacity were key measures (Rose, Løkkegaard, Sonne-Holm, & Jensen, 2013). Walking, running, skipping, jumping, and sprinting inside the AlterG® were included in the protocol design. All variables had statistically significant differences by the end of the intervention. These improvements supported the researcher's aim for the training design to improve quality of life for participants; these results support the conclusion that LBPP is considered feasible and beneficial for this clinical population to exercise in.

Research on exercise in LBPP has shown to provide benefits within a variety of clinical exercise settings, with little to no adverse effects. This multi-functionality makes the AlterG® a useful and applicable tool for rehabilitation and training programs.

Ankle Weights at 100% Body Weight

The use of ankle weights is an essential element of this study design. One study that examined the effects of additional loads on running mechanics, used 0.45 kg (0.99 lb.) for female and male participant's ankle weights (Claremont & Hall, 1987). Non-competitive runs were simulated with a 30-minute run for participants and VO_2 , RER, HR, and caloric expenditure were measured during trials. Variables from the ankle weight condition did not significantly vary from the unloaded control.

Information from this study contributed to the selection of 0.64 kg (1.4 lb.) as the ankle weight per leg that were added to participants during their weighted condition test. Ankle weights were slightly heavier and participants were not required to run for a long duration of time. The primary reason for adding weights was to measure muscle activity, to

observe how much additional activity the ankle weights created. The current research study was performed in LBPP, unlike Claremont and Hall's (1987) at full bodyweight.

A second ankle weight study assessed blood pressure responses to walking with hand weights, wrist weights, and ankle weights. The ankle weight condition did not have elevated systolic or diastolic blood pressure responses, and participants walking with ankle weights did not experience elevated RPE levels (Graves, Martin, Miltenberger, & Pollock, 1987). This study supported the notion that the use of ankle weights at lower body positive pressure would not be overly demanding for a person walking or running at partially supported body weight.

This research design excludes the use of hand-held weights due to the limited effect they have on oxygen consumption and respiratory exchange ratios. It has been found that hand held weights of 2.27 kg or less have no significant impacts on those physiological variables while walking or running on the treadmill (Owens, Al-Ahmed, & Moffatt, 1989). Ankle weights were chosen in this study design so muscle activity in the lower limbs could be studied. Generally patients exercising using the AlterG® will have experienced a lower body injury; ankle weights may have a significant impact in rehabilitation whereas hand held weights will not impact the affected limbs.

EMG

Electromyography is a technique used to estimate the size of neuromuscular transmissions and electrical activity of muscle groups in the human body (McQuillen, 1977). Muscle action potentials (MAP) are measured via electrodes placed in or over the muscles and nerves analyzed. MAP size is expressed as the number of motor units responding to a nerve stimulation, typically with units of millivolts of amplitude. McQuillen reported that

MAP size “will decrease whenever there is a functional or anatomical decrease in muscle, of whatever cause” (1977, p. 286). From these electrical stimuli we can estimate activity of certain muscles during exercise.

Extensive research exists regarding the proper placement of EMG electrodes in order to achieve optimal signals. If an electrode is placed too close to a muscle head or innervation zone, EMG signals can become distorted; electrodes should be placed according to the fibers of the specific muscle and closer over the belly of the muscle. In one particular study the methodology for identifying muscles in the lower limbs were assessed. Amongst other lower limb muscles, the gastrocnemius, tibialis anterior, and vastus medialis innervation zones were clarified (Saitou, Masuda, Michikami, Kojima, & Okada, 2000). This information was imperative for locating participant’s muscles in the current research study.

There has been one study to observe lower limb electromyography activity while running at LBPP. Eleven participants were involved and all analyses were on the right lower limb, consisting of 12 muscles total. EMG activity was recorded every 20 seconds as participants ran at $4.47 \text{ m}\cdot\text{s}^{-1}$ for two minute bouts at 100, 80, 60, and 40% body weight (Hunter et al., 2014). Results found that lower amplitudes were shown as body weight support increased. Only two muscle groups, hip adductors and medial and lateral hamstrings, did not have a significant decrease in muscle activation as body weight decreased.

These findings are interesting as they are possibly the only current data that exists on EMG activity in lower body positive pressure. The current research study proposed to maintain body weight support and increase muscle activity by adding ankle weights. EMG measurements were used to measure the differences between walking and running with and without weights; the aim of using EMGs was to record differences in muscle activation

between conditions, in the hopes of supporting the use of ankle weights in lower body positive pressure and rehabilitative settings.

Summary

Unweighting techniques have developed to the point that upright bilateral walking and running on a treadmill is possible. Lower body positive pressure has been found as a safe and effective rehabilitative technology for patients and athletes afflicted by injury. The AlterG® Treadmill is a popular new tool in which people rehabilitate and exercise. It has been observed that metabolic data such as oxygen consumption, RER, and heart rates, are not negatively impacted when performing exercise at a condition other than 100% body weight.

The use of electromyography in lower body positive pressure has not been thoroughly examined, only one article has been published that investigates muscle activity in LBPP (Hunter et al., 2014). The current research project proposed to examine muscle activity at LBPP and how the addition of ankle weights affected muscle activity. It was expected that metabolic response and muscle activity would increase with the addition of ankle weights. The intention of this research was to apply newfound knowledge to rehabilitative techniques, aiding patients in strengthening their lower body while performing at less than full body weight.

CHAPTER 3

METHODOLOGY

Lower body positive pressure is a relatively new technology and subject of research. Research on metabolic response to lower body positive pressure exercise such as in the AlterG® treadmill has grown over the last ten years. This study was an analysis of metabolic response and muscle activity while exercising in LBPP, designed to examine the effects of additional external weights on walking and running. No current research exists on these variables in LBPP, while also comparing reduced body weight and reduced body weight with ankle weights, creating an increase in mass. The SUNY Cortland Institutional Review Board reviewed and accepted the proposed experiment design and associated forms on February 21st, 2017. (See Appendices A and B).

Participants

Participants were recruited from the State University of New York College at Cortland, ages 18-26 years old. A G*Power software analysis estimated an ideal sample size of 15 (Faul, Erdfelder, Lang, & Buchner, 2007). Research conducted by Hunter et al. (2014), Grabowski (2010), and Raffalt et al. (2013), was also considered for determining final sample size. Running experience was not required before walking and running in the study; current athletes from any SUNY Cortland division III team were excluded from participating. Additionally any prospective participant that had suffered a lower body injury within the past 12 months of the study was excluded. These were described as any injury that occurred from the waist down on the individual. There was no gender specific selection when pooling participants; all were randomly selected prior to testing. The lead researcher assigned each participant an identification number to maintain anonymity when reporting data.

Instruments

All testing was performed in the SUNY Cortland exercise physiology laboratory. The majority of data were collected via the metabolic cart; this cart included a computer with a metabolic data collection software program and the electromyography software.

The metabolic data collection program was the Breeze Suite 8.3 Software package, from MGC Diagnostics. It collected all metabolic information: oxygen consumption, respiratory exchange ratios, and heart rates. A neoprene mask secured over a person's nose and mouth, that was critical for metabolic data collection; the mask had a breathing tube in front of the mouth that connected to the metabolic cart, it continuously captured oxygen and carbon dioxide input and output from the participant.

For collecting muscle activity data the BTS FREEEMG 1000 Version 1 was used. The electrodes were wireless and had a small "satellite" and larger "mother" component. Data from electrodes were captured via the "mother" electrode and sent to the EMG analyzer on the metabolic cart.

The AlterG® Anti-Gravity Treadmill® M320 was used throughout the experiment to create the lower body positive pressure environment subjects exercised in. The AlterG® Treadmill requires neoprene shorts that must be worn in the machine to create the lower body positive pressure chamber. The shorts are approximately knee-length and worn more close-fitting than loose. A two-inch zippered skirt rims the perimeter of the shorts, allowing a person to zip into the treadmill and fully enclose their lower body. There are sizes ranging from XS-XXXL to accommodate different body types.

The ankle weights were 0.64 kg (1.4 lb.) each, 1.28 kg (2.8 lb.) total. The weights had Velcro around the edges to fasten them around the ankle.

A Polar T31-coded heart rate heart monitor was worn on the skin across the participant's sternum. This heart rate tracking system had a receiver connected to the metabolic cart and recorded data in the Breeze software program.

The Borg Rating of Perceived Exertion scale was used during the exercise protocol. This scale ranges from 6-20, 6 meaning "no exertion at all" and 20 defined as "maximal exertion". The research assistant held up the RPE scale for participants to report how they subjectively felt during the exercise protocol.

Other instruments included were a standard weight scale to measure participant's weight and the physician's height scale for participant's height, provided in the exercise physiology laboratory.

Design & Procedures

Email and word-of-mouth was used on SUNY Cortland campus to recruit college-aged participants. The researcher randomly selected 16 names from a list of possible volunteer participants. The final 16 people were notified via email they had been selected and given specific instructions not to consume caffeine or exercise before their testing sessions (See Appendix D).

Each participant ran once at 60% body weight without ankle weights (NW) and a separate time with ankle weights (AKW). The research assistant randomly selected the weight condition when participants came to a session. One condition was performed on the first day of testing; participants returned at least 24-hours later to do the other condition.

For the first test session the participant entered the lab and filled out an informed consent form and Physical Activity Readiness Questionnaire (PAR-Q) and (Appendices B and C). In a separate room height and weight was recorded, without shoes on. The research

assistant placed a heart rate monitor on the subject. They were then fitted for the appropriate sized AlterG® neoprene shorts and given time to change.

Electrodes were placed on clean-shaven skin, medially over the muscles intended for study. Manual contractions or resistance were used to palpate each muscle. The lead researcher applied electrodes to participant's gastrocnemius, tibialis anterior, and vastus medialis muscles on the right leg as per Hunter et al. (2014). The researcher referenced work by Rainoldi, Melchiorri, and Caruso (2004) specifically to avoid innervation zones and maintain uniformity for proper placement of each electrode. The mother and satellite components were spaced apart with a 3 cm dowel to keep spacing consistent for each application. Athletic tape was placed around the electrode and limb to secure the electrodes in place.

Next the researcher instructed the participant to enter the chamber of the treadmill then adjusted the height of the chamber to align with the iliac crest of the participant. The participant was zipped in then stood in ready position: a slight bend in the knees and arms crossed in an X-shape across the chest. Calibration began as the machine fully pressurized the chamber around the lower body to measure the participant's weight and returned to zero pressure (100% body weight).

If the participant ran in the ankle weight condition there was an additional step before proceeding with the protocol; the researcher half un-zipped the skirt that secured the subject into the treadmill to hand them one ankle weight at a time to put on. Once the ankle weights were on, the skirted perimeter of the shorts was re-zipped to enclose the lower body again in the chamber. If they were performing the no weight condition there was no extra step once secured in the treadmill.

The participant was then adjusted to 60% body weight. The lead researcher situated a neoprene mask over the participant's nose and mouth. The mask connected to the metabolic cart and the Breeze software program that continuously captured metabolic data. Figure 1 displays the progression of a participant's visit based on the condition they were being tested.

To begin the protocol, treadmill speed was set to $1.34 \text{ m}\cdot\text{s}^{-1}$ (3 mph), the walking portion of the test. The participant walked for four minutes. Data were continuously collected via the mask to metabolic cart and by EMG electrodes. At three minutes and thirty seconds, EMG data were recorded until the fourth minute. At the fourth minute of walking, the research assistant held up the RPE scale for the participant to report, either verbally or by pointing to a number, how they felt.

After the fourth minute of walk speed was increased to $2.68 \text{ m}\cdot\text{s}^{-1}$ (6 mph). Thirty seconds before the end of the stage EMG amplitudes were recorded. At the fourth minute of running RPE was again recorded. A data collection sheet was used to record real-time data at the four-minute marks (See Appendix E). After the fourth minute of run the participant was brought down to a walk then complete stop and the test ceased. The exercise test protocol is displayed in Figure 2. The mask was removed and the participant was unzipped from the treadmill. Once unzipped participants were taken into a separate room to change, take off electrodes, and AlterG® shorts, then were free to leave the testing area.

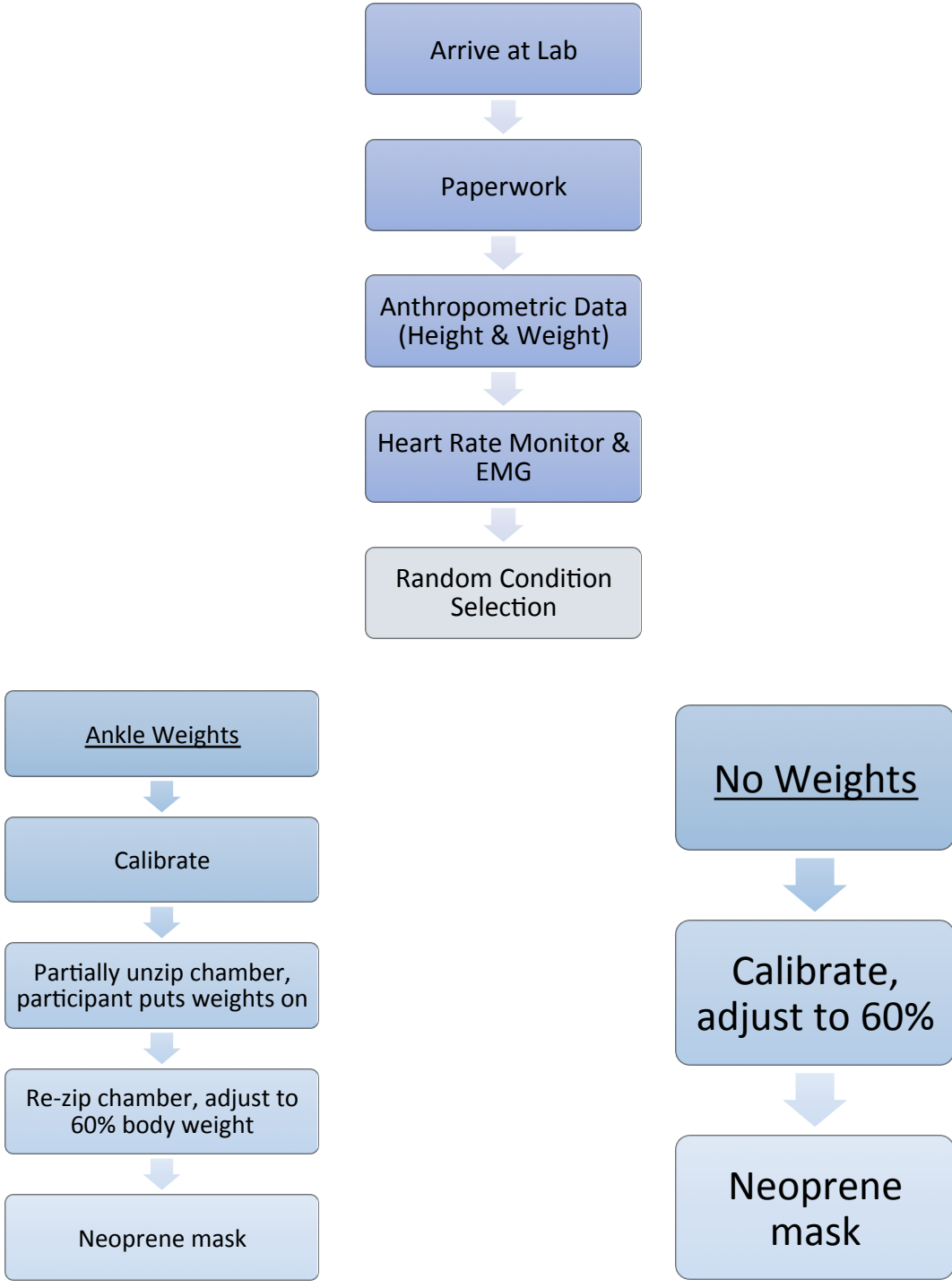


Figure 1. Pre-test calibration procedure. This figure illustrates how a participant was calibrated depending on test day condition.

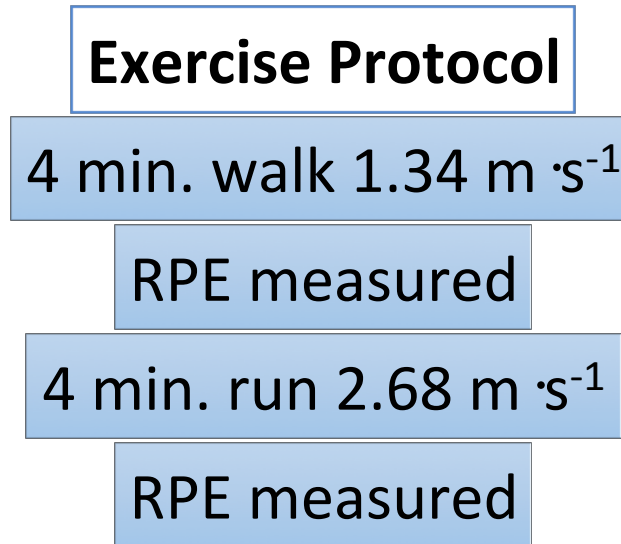


Figure 2. Participant exercise protocol. This figure represents the exercise protocol participants performed, once at the NW and once at the AKW condition.

An additional step in data collection was necessary to normalize EMG amplitudes later in data analysis. Each participant walked and ran at the same speeds from the exercise protocol for 30s each on a regular treadmill while wearing EMG electrodes. This was randomly done once for each participant before one testing session to obtain 100% body weight EMG data; the process was not repeated, and they were given five minutes to recover before beginning the actual exercise protocol. These recordings were used in the data analysis to normalize AlterG® EMG amplitudes to 100% body weight.

Data Analysis

Metabolic data were taken from the Breeze software and processed in Microsoft excel. VO_2 , RER, and HR data were taken from the fourth and eighth minutes of the exercise protocol. Caloric expenditure was calculated in excel by using absolute VO_2 from the fourth and eighth minutes of exercise; absolute VO_2 expressed in mLO_2/min was converted to LO_2/min , then changed to kcal based on $1\text{LO}_2 \approx 5 \text{ kcal}$ (Scott, 2005).

There were several steps for EMG amplitudes analysis. First, root mean squares of the 30s recordings were calculated, in millivolts. This was done for each muscle at both speeds and weight conditions, per participant. These values were then divided by the root mean square signal means in millivolts, from the 100% body weight recordings. This was done to normalize AlterG® amplitudes to full body weight as per Hunter, et al. (2014). The data were then multiplied by 100 to be expressed as a percent.

$$\left(\frac{60\% \text{ BW RMS mV}}{\text{signal mean } 100\% \text{ BW RMS mV}} \right) * 100 = \text{Normalized Amplitude (\%)}$$

From these data, maximum peak values over the course of the 30s were averaged to find final EMG amplitudes. All EMG data in the results are expressed as an average of the maximum peaks over the 30s time period, at the end of walking or running stages.

IBM SPSS statistical software version 23 was used for data analysis. A two-way analysis of variance (ANOVA) with repeated measures and a Bonferroni post-hoc compared mean values of all variables at 1.34 m·s⁻¹ (walk) and 2.68 m·s⁻¹ (run). Treadmill speed and weighted condition (NW vs. AKW) were the within-subjects variables. VO₂, RER, HR, caloric expenditure, RPE, and EMG (gastrocnemius, tibialis anterior, and vastus medialis) were the dependent variables.

CHAPTER 4

RESULTS AND DISCUSSION

The purpose of this study was to determine if there were differences in metabolic response and RPE while walking and running in LBPP with and without ankle weights. A secondary purpose was to compare muscle electromyography amplitudes of three lower limb muscles while walking and running in lower body positive pressure with and without ankle weights. Participants went through two separate testing sessions at 60% body weight in LBPP: one no weight condition and one ankle weight condition. Descriptive statistics of participants were recorded and displayed in Appendix F. Data for the eight dependent variables were obtained from the two separate testing sessions and analyzed in this section.

Results

Means and stand deviations of NW and AKW data at $1.34 \text{ m}\cdot\text{s}^{-1}$ are presented in Table 1. Fourteen participants' metabolic data were analyzed and 16 participants' data were used for RPE and EMG data.

Table 1

Walking ($1.34\text{m}\cdot\text{s}^{-1}$) Metabolic Data at 60% Body Weight

Variable	n	Condition			
		NW		AKW	
		M	SD	M	SD
<i>VO₂ (mlO₂/kg/min)</i>	14	10.4	(±1.49)	12.2	(±1.46)
<i>RER (VCO₂/VO₂)</i>	14	0.89	(±.064)	0.87	(±.061)
<i>HR (bpm)</i>	14	103	(±17.3)	99.4	(±13.3)
<i>Caloric Expenditure (kcal)</i>	14	14.4	(±4.90)	16.8	(±4.77)
<i>RPE</i>	16	7.00	(±1.00)	7.00	(±1.00)
<i>EMG Gastrocnemius (%)</i>	16	560.5	(±181.9)	586.5	(±237.6)
<i>EMG Tibialis Anterior (%)</i>	16	570.4	(±158.9)	581.2	(±363.3)
<i>EMG Vastus Medialis (%)</i>	16	606.7	(±441.8)	521.8	(±537.0)

Note. The * indicates significance at the $p < 0.05$ level. EMG data maximum peaks values from the 30s recording were averaged and are expressed as a percentage, normalized to 100% body weight.

Table 2 compares means and standard deviations of NW and AKW data at the 2.68 m·s⁻¹ speed. Fourteen participants' data were analyzed for metabolic data, while the full 16 were analyzed for RPE and EMG data.

Table 2

Running (2.68m·s⁻¹) Metabolic Data at 60% Body Weight

Variable	n	Condition			
		NW		AKW	
		M	SD	M	SD
<i>VO₂ (mlO₂/kg/min)</i>	14	20.3	(±3.38)	23.3	(±4.86)
<i>RER (VCO₂/VO₂)</i>	14	0.95	(±0.063)	0.96	(±0.077)
<i>HR (bpm)</i>	14	140	(±21.1)	144	(±20.3)
<i>Caloric Expenditure (kcal)</i>	14	28.1	(±9.16)	31.9	(±10.2)
<i>RPE*</i>	16	9.00	(±2.00)	11.00	(±1.00)
<i>EMG Gastrocnemius (%)</i>	16	485.0	(±124.6)	461.2	(±171.7)
<i>EMG Tibialis Anterior (%)</i>	16	647.7	(±443.5)	546.9	(±377.2)
<i>EMG Vastus Medialis (%)</i>	16	448.2	(±316.0)	633.3	(±629.9)

Note. The * indicates significance at the $p < 0.05$ level. EMG data maximum peaks values from the 30s recording were averaged and are expressed as a percentage, normalized to 100% body weight.

A two-way repeated measures ANOVA determined there was not a significant interaction of speed and weighted condition on VO₂, $F(1,13) = 1.712$, $p = .213$, partial $\eta^2 = .116$. Average oxygen consumption data at both speeds and weighted conditions are presented in Figure 3.

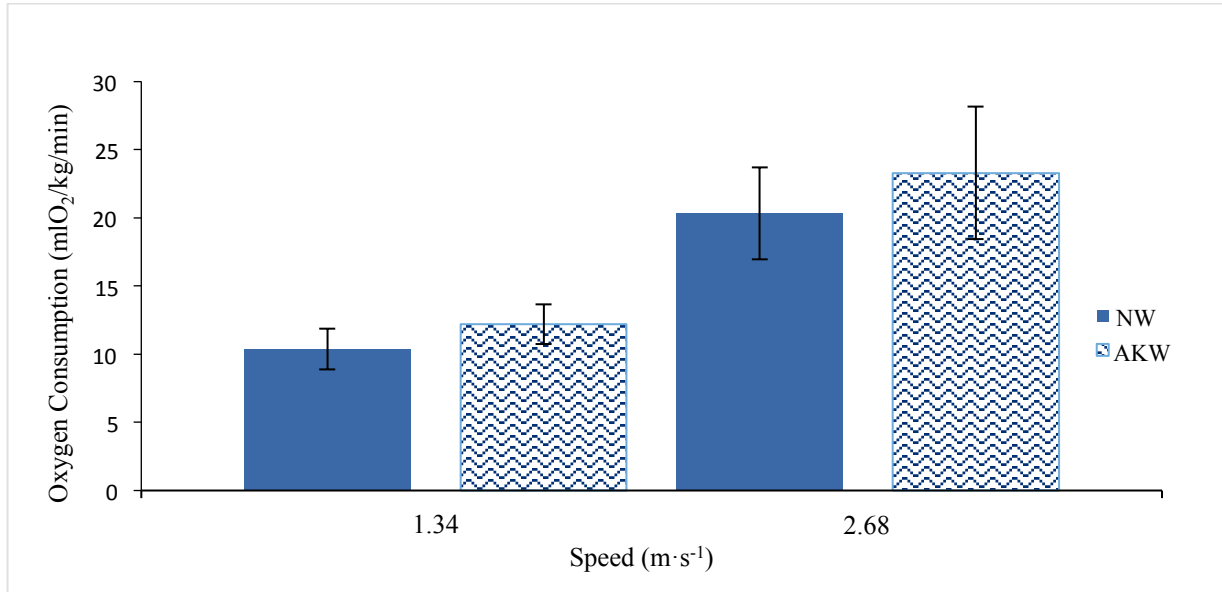


Figure 3. A comparison of mean steady state VO₂ at walk and run at 60% body weight. Solid bars represent the NW condition and lined bars represent the AKW condition. Data were taken from the fourth (end of walk) and eighth minute (end of run) of exercise. No statistically significant interactions between speed and weighted condition were found.

To determine the effect of speed and weighted condition on RER a two-way repeated measures ANOVA was run. There was a statistically significant interaction; $F(1,13) = 4.834$, $p < .05$, partial $\eta^2 = .271$, therefore simple main effects were run. At $1.34 \text{ m}\cdot\text{s}^{-1}$, RER was not statistically significantly different between the two weighted conditions, $F(1,13) = 3.411$, $p = .088$, partial $\eta^2 = .208$. At $2.68 \text{ m}\cdot\text{s}^{-1}$, RER was not statistically significantly different between the two weighted conditions, $F(1,13) = .350$, $p = .564$, partial $\eta^2 = .026$.

For the NW condition RER was statistically significantly different between the two speeds, $F(1,13) = 8.444$, $p < .05$, partial $\eta^2 = .394$. Post hoc analysis with a Bonferonni adjustment indicated that RER increased significantly from $1.34 \text{ m}\cdot\text{s}^{-1}$ to $2.68 \text{ m}\cdot\text{s}^{-1}$. Specifically, RER was statistically higher at $2.68 \text{ m}\cdot\text{s}^{-1}$ than at $1.34 \text{ m}\cdot\text{s}^{-1}$, ($M = .062$), 95% CI [.016, .108], $p < .05$. At the AKW condition RER was also statistically significantly different between the two speeds, $F(1,15) = 26.413$, $p < .05$, partial $\eta^2 = .638$. Post hoc analysis with a Bonferonni adjustment indicated that RER increased significantly from 1.34

$\text{m}\cdot\text{s}^{-1}$ to $2.68 \text{ m}\cdot\text{s}^{-1}$. RER was statistically higher at $2.68 \text{ m}\cdot\text{s}^{-1}$ than at $1.34 \text{ m}\cdot\text{s}^{-1}$, ($M = .090$), 95% CI [.053, .127], $p < .05$. The mean data for RER at both speeds and weighted conditions are presented in Figure 4.

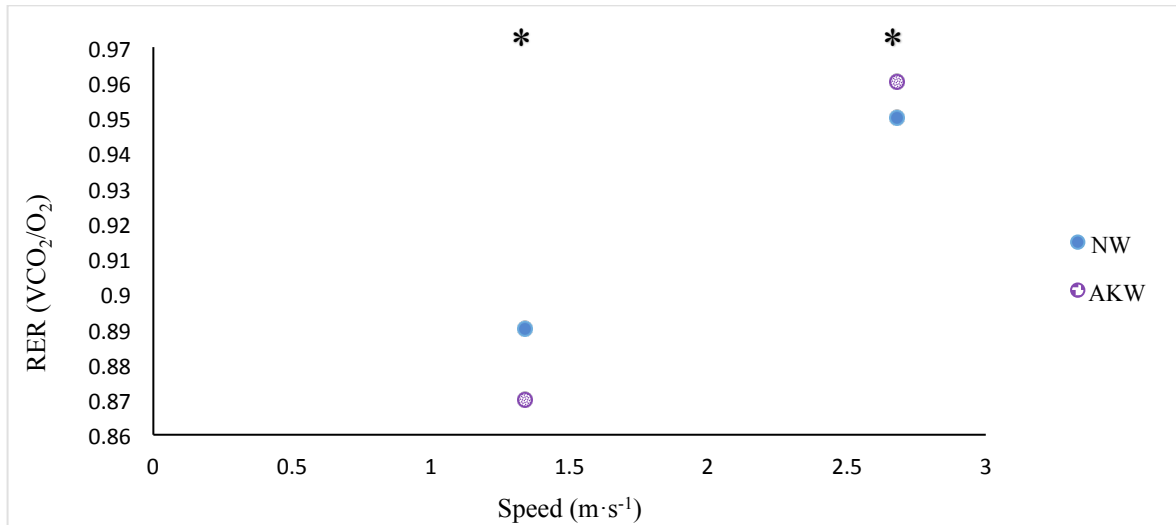


Figure 4. A visual representation of significant differences in RER from walk to run at 60% body weight. Solid points represent the NW condition and patterned points represent AKW. Data were taken from the fourth and eighth minutes of the exercise protocol. Statistically significant differences between speeds within weighted condition are indicated by *.

After running a two-way repeated measures ANOVA to determine the effect of speed and weighted condition on HR there was no significant interaction found, $F(1,13) = 1.101$, $p = .313$, partial $\eta^2 = .078$. Figure 5 presents average HR data at both speeds and weighted conditions.

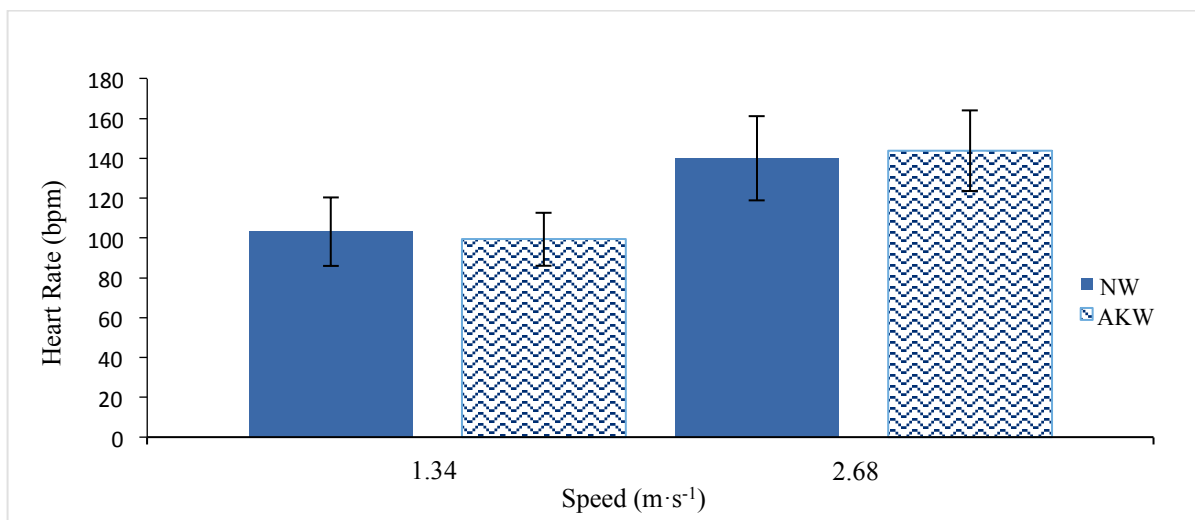


Figure 5. A comparison of mean steady state heart rate values at walk and run at 60% body weight. Solid bars represent NW and lined bars represent AKW conditions. Data were taken from the fourth and eighth minutes of exercise. There were no statistically significant interactions between speed and weighted condition on heart rate.

A two-way repeated measures ANOVA was run to determine the effect of speed and weighted condition on caloric expenditure. No significant interactions were found, $F(1,13) = 1.940$, $p = .187$, partial $\eta^2 = .130$. Average caloric expenditure data at both speeds and weighted conditions are presented in Figure 6.

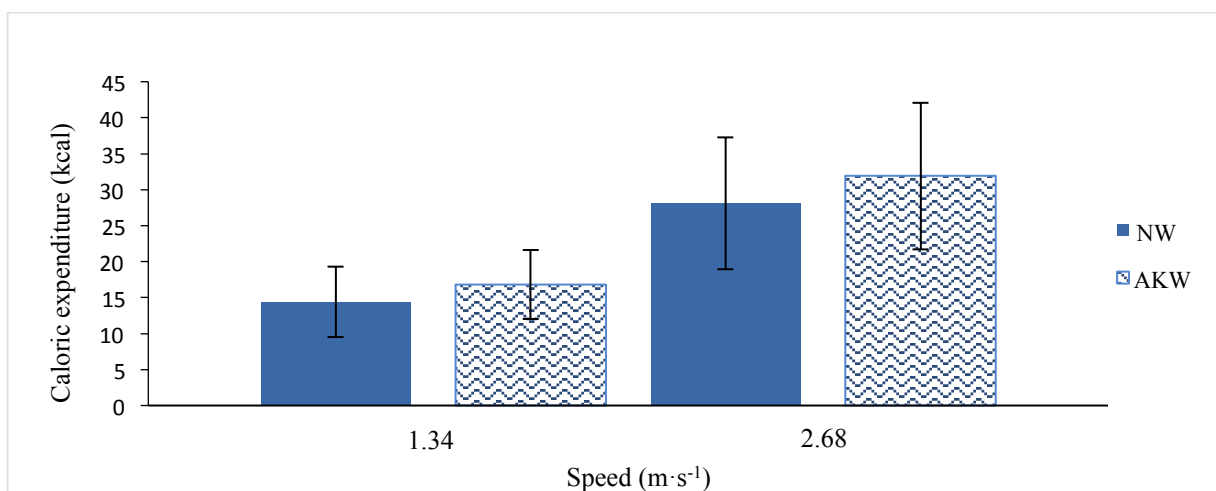


Figure 6. A comparison of mean caloric expenditure at walk and run at 60% body weight. Solid bars represent NW and lined bars represent the AKW condition. Data were taken from the fourth and eighth minutes of exercise. There were no statistically significant interactions between speed and weighted condition on caloric expenditure.

A two-way repeated measures ANOVA determined statistically significant interactions of speed and weighted condition on RPE, $F(1,15) = 6.505, p < .05$, partial $\eta^2 = .303$. Simple main effects were run; at $1.34 \text{ m}\cdot\text{s}^{-1}$ RPE was not statistically significantly different between weighted conditions, $F(1,15) = 1.709, p = .211$, partial $\eta^2 = .102$. At $2.68 \text{ m}\cdot\text{s}^{-1}$ RPE was statistically significantly different between weighted conditions, $F(1,15) = 18.138, p < .05$, partial $\eta^2 = .547$. A Bonferonni post hoc adjustment indicated RPE increased significantly from NW to AKW; RPE was statistically higher with ankle weights than with no weight. ($M = 1.063$), 95% CI [.531, 1.594], $p < .05$, indicated in Figure 7.

For the NW condition RPE was statistically significantly different between the two speeds, $F(1,15) = 28.846, p < .05$, partial $\eta^2 = .658$. Post hoc analysis with a Bonferonni adjustment indicated RPE increased significantly from $1.34 \text{ m}\cdot\text{s}^{-1}$ to $2.68 \text{ m}\cdot\text{s}^{-1}$. RPE was statistically higher at $2.68 \text{ m}\cdot\text{s}^{-1}$ than at $1.34 \text{ m}\cdot\text{s}^{-1}$. ($M = 2.500$), 95% CI [1.508, 3.492], $p < .05$. For the AKW condition RPE was statistically significantly different between the two speeds, $F(1,15) = 57.459, p < .05$, partial $\eta^2 = .793$. Post hoc analysis with a Bonferonni adjustment indicated RPE increased significantly from $1.34 \text{ m}\cdot\text{s}^{-1}$ to $2.68 \text{ m}\cdot\text{s}^{-1}$. RPE was statistically higher at $2.68 \text{ m}\cdot\text{s}^{-1}$ than at $1.34 \text{ m}\cdot\text{s}^{-1}$. ($M = 3.188$), 95% CI [2.291, 4.084], $p < .05$. These results can also be found in Figure 7.

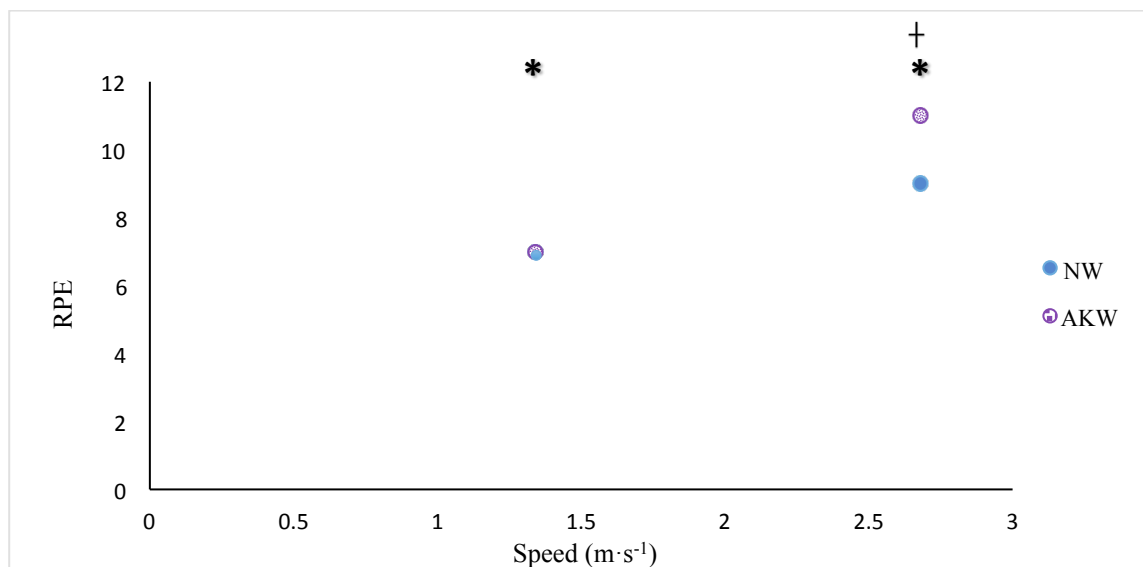


Figure 7. A visual representation of significant differences for RPE at 60% body weight. Solid points represent the NW condition and patterned points represent AKW. Data were taken from the fourth and eighth minutes of the exercise protocol. Statistically significant differences between speeds at both conditions are indicated by *. The † indicates there was a statistically significant difference between NW and AKW at 2.68 m·s⁻¹.

A two-way repeated measures ANOVA was run to determine the effect of speed and weighted condition on EMG of the gastrocnemius as well as EMG of the tibialis anterior. There was not a significant interaction between speed and weighted condition on EMG of the gastrocnemius, $F(1,15) = .728, p = .407, \text{partial } \eta^2 = .046$. There was not a significant interaction for EMG of the tibialis anterior between speed and weighted condition, $F(1,15) = 1.006, p = .332, \text{partial } \eta^2 = .063$.

A two-way repeated measures ANOVA determined there was a statistically significant interaction between speed and weighted condition on EMG of the vastus medialis, $F(1,15) = 4.767, p < .05, \text{partial } \eta^2 = .241$. Simple main effects were run. At 1.34 m·s⁻¹, EMG of the vastus medialis was not statistically significantly different between the two weighted conditions, $F(1,15) = .470, p = .503, \text{partial } \eta^2 = .030$. At 2.68 m·s⁻¹, EMG of the vastus medialis was not statistically significantly different between the two weighted conditions, $F(1,15) = 1.897, p = .189, \text{partial } \eta^2 = .112$.

For the NW condition, EMG of the vastus medialis was not statistically significantly different between the two speeds, $F(1,15) = 2.735$, $p = .119$, partial $\eta^2 = .154$. At the AKW condition, EMG of the vastus medialis was also not statistically significantly different between the two speeds, $F(1,15) = 1.745$, $p = .206$, partial $\eta^2 = .104$. Mean peak amplitudes of the gastrocnemius, tibialis anterior, and vastus medialis for NW and AKW conditions at $1.34 \text{ m}\cdot\text{s}^{-1}$ are presented in Figure 8. Mean peak amplitudes for both weighted conditions of the three muscles at $2.68 \text{ m}\cdot\text{s}^{-1}$ are presented in Figure 9.

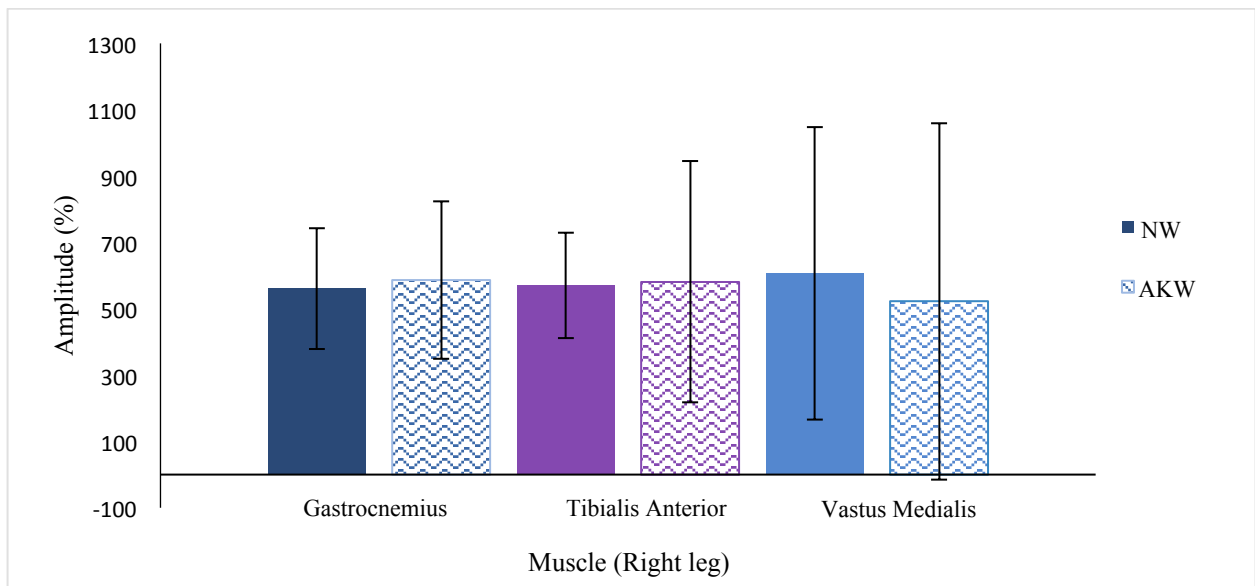


Figure 8. Normalized mean maximum EMG amplitudes at $1.34 \text{ m}\cdot\text{s}^{-1}$ at 60% body weight. Solid bars represent NW and lined bars represent AKW conditions. Peak values from the 30s recordings were averaged to represent EMG activity while walking. There were no statistically significant interactions between speed and weighted condition among the three muscles.

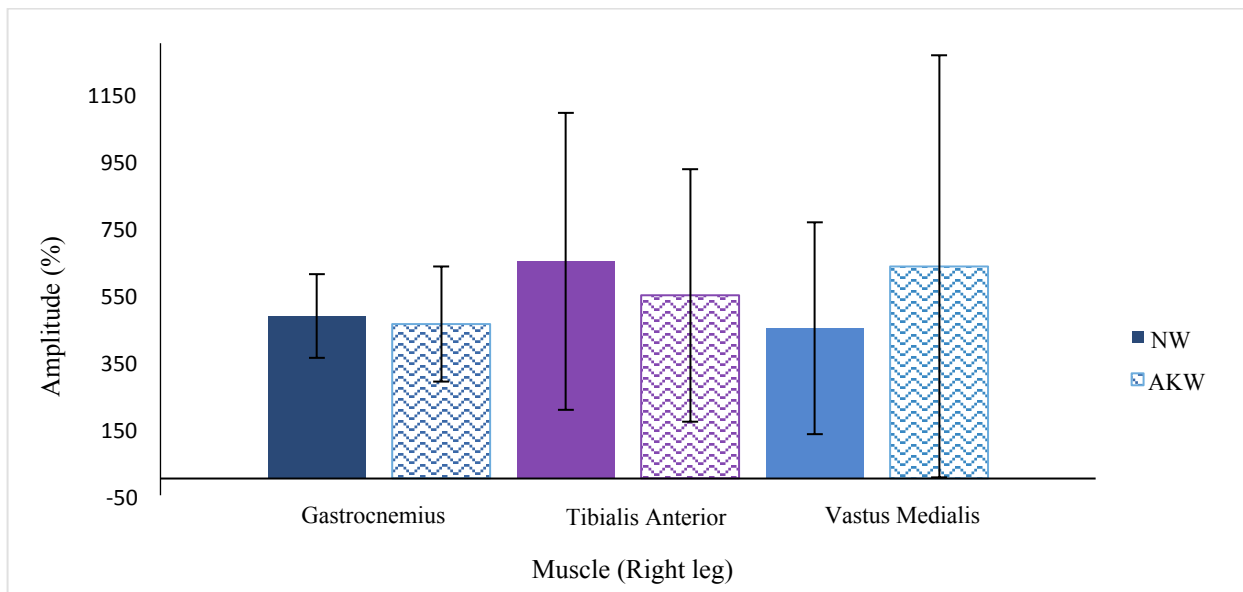


Figure 9. Normalized mean maximum EMG amplitudes at $2.68 \text{ m}\cdot\text{s}^{-1}$ at 60% body weight. Solid bars represent NW and lined bars represent AKW conditions. Peak values from the 30s recordings were averaged to represent EMG activity while running. There were no statistically significant interactions between speed and weighted condition for the gastrocnemius or tibialis anterior. A two-way repeated measures ANOVA indicated a statistically significant interaction for the vastus medialis, but post hoc analyses found no true significant differences between speed and weighted conditions.

Discussion

Results from the current research study varied for several reasons. Ongoing complications throughout the data collection process resulted in the loss of two participants' NW trial metabolic data, thus 14 metabolic data sets were analyzed rather than 16. Additionally, the final sample size was only one participant higher than predicted ideal from the power analysis, which may have influenced results. A larger sample size could have provided substantial data to observe statistically significant differences in metabolic variables. The selected speed of $2.68 \text{ m}\cdot\text{s}^{-1}$ may also have been a contributing factor; for some individuals $2.68 \text{ m}\cdot\text{s}^{-1}$ (6mph) is not challenging and might be considered more of a jog as opposed to a run.

Although there were no statistically significant differences in oxygen consumption levels, the AKW condition had greater oxygen consumption at both speeds; AKW VO_2 was ~17% higher than NW when walking and ~15% higher than NW when running. Further research with a larger sample size, faster speed conditions, and ankle weights adjusted according to specific participants may be worthwhile to observe greater differences in VO_2 .

Significant differences in RER occurred within NW and AKW conditions going from $1.34 \text{ m}\cdot\text{s}^{-1}$ to $2.68 \text{ m}\cdot\text{s}^{-1}$. This was an expected result regardless of additional weight, due to changes in physiological demand required going from walking to running (Ramos-Jiménez, et al., 2008). The second speed of $2.68 \text{ m}\cdot\text{s}^{-1}$ was a higher intensity exercise and required more carbohydrate fuel sources, raising RER to values of 0.9 and above.

There were no significant differences between NW and AKW condition at either speed on RER, the mean values were about equivalent for walking and running. Had participants been at 100% body weight rather than 60% body weight, a larger difference may have occurred but the benefits of LBPP would be lost.

Heart rate was not statistically significantly different for any speed versus weighted condition. This result was not unexpected, as walking at $1.34 \text{ m}\cdot\text{s}^{-1}$ was not associated as a highly intense speed. Performing this exercise was not meant to be overly taxing, so a similar response in heart rate between conditions was not considered unfavorable. An interesting result was there were no RPE reported above 14, which matched mean HR values of ~140 bpm while running. At $2.68 \text{ m}\cdot\text{s}^{-1}$ the lack of a large difference between conditions could have resulted from the ankle weights being 0.64 kg each, a set weight that might not have been heavy enough for all participants. Increasing how much the ankle weights weigh

according to each individual could contribute to greater differences in heart rate if necessary in future research.

Caloric expenditure increased from NW to AKW conditions although the change was not statistically significantly different. Walking values increased ~17% from NW to AKW and running values increased ~14% from NW to AKW condition. Variability in this measure may have been because previous exercise history was not assessed; it was unknown if certain participants were more active in cardiovascular exercise than others. Again, the run condition speed of $2.68 \text{ m}\cdot\text{s}^{-1}$ may have played a role. That particular speed may not have been challenging enough to increase caloric expenditure for people that run regularly, especially within a four-minute duration. A larger sample size, participant exercise background, and varied run speeds could lead to a more in-depth analysis in the future.

Rating of perceived exertion had statistically significant differences going from $1.34 \text{ m}\cdot\text{s}^{-1}$ to $2.68 \text{ m}\cdot\text{s}^{-1}$ at both NW and AKW conditions. This was an expected response as the exercise workload changed from a walk to a run. In regards to weighted condition, there was no significant difference at $1.34 \text{ m}\cdot\text{s}^{-1}$ but there was a statistically significant difference at $2.68 \text{ m}\cdot\text{s}^{-1}$ between NW and AKW. This is attributed to the additional ankle weights.

The ankle weights likely made exercise feel subjectively more difficult for participants while running. To apply these findings to rehabilitation specifically, individuals that wish to maintain a certain LBPP setting can use this technique. If hesitant to move up from 60 to 70% body weight but still wishing to subjectively increase intensity, ankle weights could be worn for several training periods, before moving on to a heavier percent body weight. It could be used as an intermediary process at each percent body weight as patients move closer to 100% body weight.

There were no statistically significant differences observed within the three electromyography variables, which had the highest standard deviations of the eight variables measured. One major factor that influenced EMG data variability was the method of analysis; the study design did not assess phases of gait while walking or running, as most EMG research does. Typical gait patterns existed but there was no way to distinguish stance or swing for certain; it was unknown which phase of motion each data point represented at any given time.

Changes in timing of muscle activation were observed and amplitudes did not vary much in pattern within weighted condition, an expected result when muscles transition from walk to run (Cappellini, 2006). Future research should assess more quadriceps and hamstring group muscles, which are more active during walking and running rather than calf muscles. Video analysis could be implemented also to identify changes from stance and swing phases to better assess data.

Due to these factors, the final analysis was on average maximum peak values from the 30s recordings of walking and running, after normalizing to 100% body weight. Mean peak amplitudes of the gastrocnemius and tibialis anterior remained similar at both speeds between NW and AKW conditions, and no statistically significant differences were observed.

At $2.68 \text{ m}\cdot\text{s}^{-1}$ there was a statistically significant difference in amplitude between speed and weighted condition on the vastus medialis, however the simple main effects tests revealed no true differences occurred for any interaction. Two participant's vastus medialis running data are displayed in Figures 10 and 11. Like the other muscles assessed, amplitudes for the vastus medialis occur at similar frequency within the same participant's recording, but vary in size between NW and AKW condition, as well as between participants.

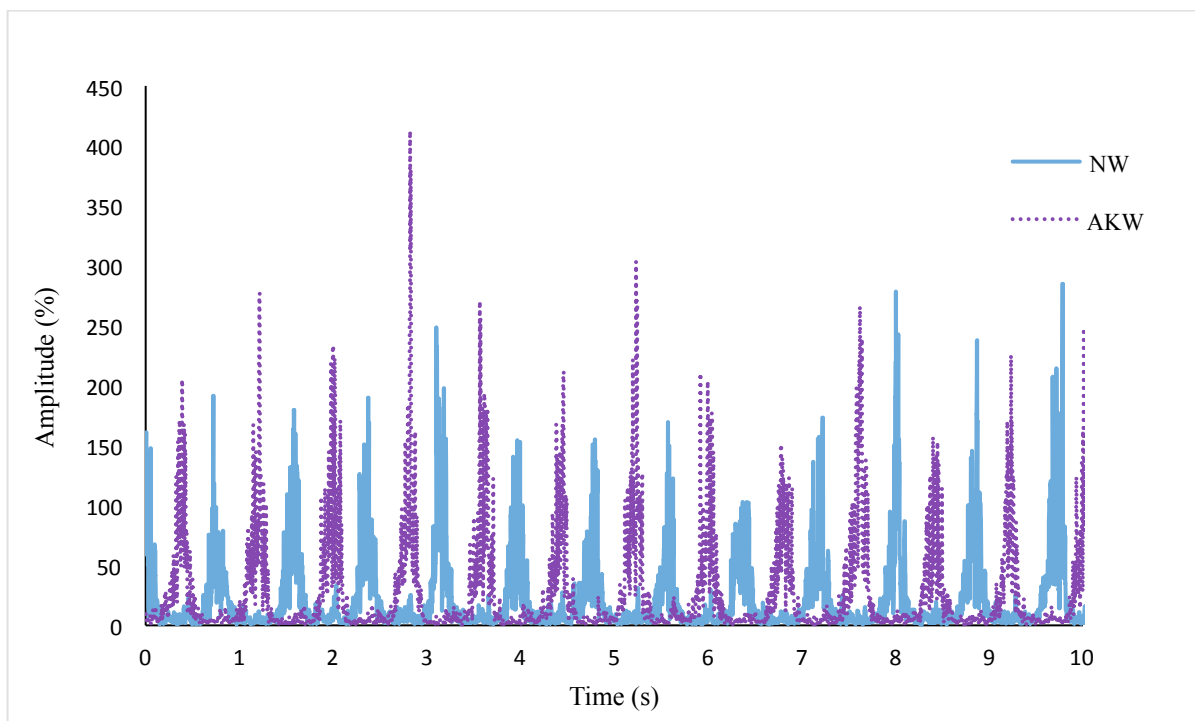


Figure 10. Participant one's normalized RMS vastus medialis EMG while running at 60% body weight. NW values are solid, AKW values are dashed. These are RMS amplitudes expressed as a percent of full body weight. This is a 10s snapshot of the 30s recording taken during the exercise protocol.

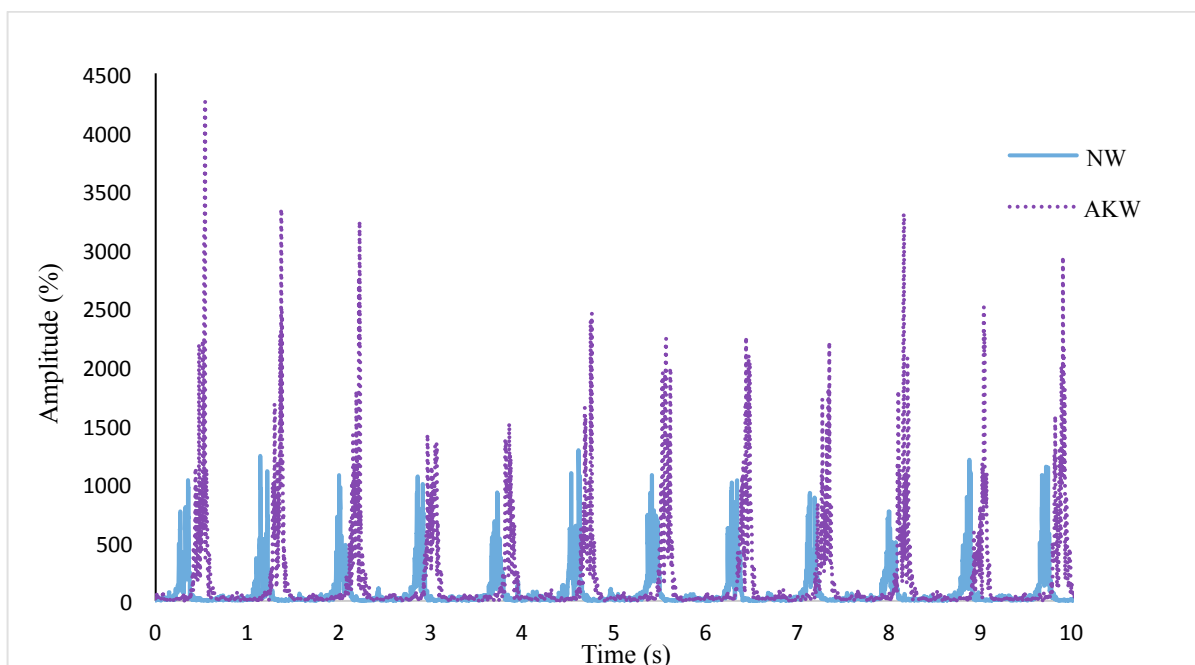


Figure 11. Participant sixteen's normalized RMS vastus medialis EMG while running at 60% body weight. NW values are solid, AKW values are dashed. These are RMS amplitudes expressed as a percent of full body weight. This is a 10s snapshot of the 30s recording taken during the exercise protocol.

Most participant data had similar plots and amplitude patterns. Data from Figures 10 and 11 show higher muscle activation amplitudes for the AKW conditions and lower amplitudes at the NW conditions, a result that was expected due to the extra mass.

The vastus medialis saw greater differences than the gastrocnemius and tibialis anterior due to typical muscle activation that occurs during running. Greater differences between NW and AKW likely occurred due to the increase in muscle activation required to pick up and swing the added mass of the ankle weights. Further research may be necessary to see if substantial differences can occur in other muscle groups while in LBPP. The particular muscles assessed in this study were not ideal for measuring differences in running EMG amplitudes. The ankle weight amount may not have been heavy enough for some subjects to experience true differences as well.

By retesting with differentiated groups of participants more reliable results may be assessed in the future. Participants could be grouped by cardiovascular training experience, and given ankle weights based on individual height and weight. Weights should not be too heavy to avoid overloading the participant, but heavier weights may be necessary for those with longer limbs. An additional running condition speed should be implemented as well.

Differences observed in metabolic variables and muscle activation may become significant if more participant factors are taken into consideration when building the exercise protocol. Additionally a protocol of this nature would more likely match a rehabilitation program that would be specific to each patient.

CHAPTER 5

SUMMARY AND CONCLUSION

Summary

The purpose of this study was to observe changes in metabolic response and rating of perceived exertion when ankle weights were added to a participant walking and running in lower body positive pressure at 60% body weight. A secondary purpose was to examine differences in muscle activity comparing no weight to ankle weight conditions in LBPP.

Sixteen college-aged participants volunteered from SUNY Cortland to partake in the study. Each participant completed two separate tests of walking and running in lower body positive pressure, while metabolic response, RPE, and electromyography amplitudes were recorded.

Analysis of the eight dependent variables found a majority of participants experienced differences going from NW to AKW conditions, however RPE at 2.68 m·s⁻¹ had the only statistically significant difference measured between weighted conditions. The lack of statistical significance in metabolic response could be attributed to the small sample size of participants, low speed of run condition, and uniform weight of ankle weights.

Although it was not found statistically significantly different, oxygen consumption increased by 17% from NW to AKW walking and 15% from NW to AKW running. Caloric expenditure also increased by 17% from NW to AKW walking and by 14% for NW to AKW running.

Electromyographic variables could not accurately be identified in stance or swing phases, which limited data analysis. There was high variability in muscle activation amplitudes among individual participants. EMG of the vastus medialis had the most

remarkable differences in maximum amplitude values, although not statistically significantly different. There were differences observed within individual data that showed NW amplitudes were typically lower than at the AKW condition. Future research should be conducted that distinguishes gait phases while in the AlterG®, with electrodes on quadriceps and hamstring muscles to gain more applicable EMG data.

Conclusion

After testing 16 participants it was observed that the addition of ankle weights had a slight effect on increasing metabolic response, rating of perceived exertion, and muscle activity but not enough to substantially increase exercise intensity or impact muscle strength while walking or running in LBPP. Further research is necessary to better understand the effectiveness of ankle weights in LBPP, if a remarkable difference can be found that benefits the user.

The current study protocol may be useful to apply as an intermediate rehabilitative or training program; patients comfortable at a certain percent body weight may apply this technique. By remaining partially supported at a weight they are comfortable in, intensity can be subjectively increased by wearing ankle weights for several training periods. Once comfortable at that stage and wishing to increase RPE again, individuals can move up to a heavier percent body weight, without ankle weights.

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APPENDIX A

Human Subjects Approval Letter**MEMORANDUM**

To: Saige Hupman
James Hokanson

From: Jena Curtis, Chair
Institutional Review Board

Date: 2/21/2017

RE: Institutional Review Board Approval

In accordance with SUNY Cortland's procedures for human research participant protections, the protocol referenced below has been approved for a period of one year:

Title of the study: Effects of ankle weights on metabolic response and muscular activity at lower body positive pressure

Level of review: Expedited	Protocol number: 161731
Project start date: Upon IRB approval	Approval expiration date*: 2/20/2018

* Note: Please include the protocol expiration date to the bottom of your consent form and recruitment materials. For more information about continuation policies and procedures, visit www.cortland.edu/irb/Applications/continuations.html

The federal Office for Research Protections (OHRP) emphasizes that investigators play a crucial role in protecting the rights and welfare of human subjects and are responsible for carrying out sound ethical research consistent with research plans approved by an IRB. Along with meeting the specific requirements of a particular research study, investigators are responsible for ongoing requirements in the conduct of approved research that include, in summary:

- obtaining and documenting informed consent from the participants and/or from a legally authorized representative prior to the individuals' participation in the research, unless these requirements have been waived by the IRB;
- obtaining prior approval from the IRB for any modifications of (or additions to) the previously approved research; this includes modifications to advertisements and other recruitment materials, changes to the informed consent or child assent, the study design and procedures, addition of research staff or student assistants, etc. (except those alterations

necessary to eliminate apparent immediate hazards to subjects, which are then to be reported by email to irb@cortland.edu within three days);

- providing to the IRB prompt reports of any unanticipated problems involving risks to subjects or others;
- following the principles outlined in the Belmont Report, OHRP Policies and Procedures (Title 45, Part 46, Protection of Human Subjects), the SUNY Cortland College Handbook, and SUNY Cortland's IRB Policies and Procedures Manual;
- notifying the IRB of continued research under the approved protocol to keep the records active; and,
- maintaining records as required by the HHS regulations and NYS State law, for at least three years after completion of the study.

Miller Building, Room 402 • P.O. Box 2000 • Cortland, NY 13045-0900

Phone: (607) 753-2511 • Fax: (607) 753-5590

Institutional Review Board
Page 2

In the event that questions or concerns arise about research at SUNY Cortland, please contact the IRB by email irb@cortland.edu or by telephone at (607)753-2511. You may also contact a member of the IRB who possesses expertise in your discipline or methodology, visit <http://www.cortland.edu/irb/members.html> to obtain a current list of IRB members.


Sincerely,



Jena Curtis, Chair
Institutional Review Board
SUNY Cortland

APPENDIX B

Informed Consent Form

State University of New York at Cortland 
Informed Consent

You are invited to participate in a thesis project conducted by graduate student Saige Hupman, in the exercise science master's program at SUNY Cortland. This is a research project that will involve physical activity and the recording of data that will be collected during the activities. Please read the following information carefully and consider whether or not you would like to participate. The researcher requires that you understand, sign, and return this informed consent agreement in order to be a participant in the study.

Project Overview

The primary purpose of this study is to measure changes in muscle activity, oxygen consumption, and caloric expenditure (how many calories are burned while exercising) while walking and running in lower body positive pressure (on an AlterG® Treadmill). The results of this study will help exercise science researchers better understand the effects of running at a reduced body weight on muscle activity, oxygen consumption, and caloric expenditure while exercising in lower body positive pressure. You are encouraged to ask any questions you may have about the project, procedure, or objectives at any time.

Procedure

Upon agreeing to participate, you will be asked to the exercise physiology laboratory (Professional studies room 1170) on two separate occasions for approximately 8 minutes of exercise on the AlterG® treadmill. There will be a walking and running portion at two speeds (3 mph and 6 mph). You will be wearing a specialized pair of neoprene shorts that secure you into the lower body positive pressure chamber that the AlterG® treadmill creates. You will also have wireless EMG electrodes on four spots of the right leg, these are noninvasive and go on the skin. You will also be wearing a breathable neoprene mask that covers the nose and mouth, this will allow the researcher to collect metabolic data (oxygen consumption) while you are exercising. During one of the exercise sessions you will wear 1.4 lb ankle weights on each leg. The other test session will not require you to wear ankle weights. Your height and body weight will be recorded using scales in the laboratory.

Risk

If you have experienced any lower body injury (including all areas from the waist down to the feet) within the past 12 months, you are not eligible to participate in this study. Participants must also be between the ages of 18-25 years of age.

There is little risk associated with your participation in this study. One associated risk may be while walking and running on the treadmill, you may feel discomfort at a certain speed due to physical exertion. The shorts are neoprene/spandex material and are worn close fitting to the body, you may experience slight discomfort wearing them in the treadmill. The oxygen consumption mask may become sweaty and warm, however it is completely breathable when exercising. The mask is secured by Velcro and can be removed at any point during the exercise session. There are no other additional known risks if you choose to volunteer for this study.

Protocol Expiration Date: 2/20/2018

Confidentiality

The researchers involved in this project will be the only people granted access to your results, which will be stored electronically on a flash drive. Concluding data collection, this flash drive will be kept at the researcher's home residence for three years, following which all data will be erased and deleted. Your name will not be tied to the data at any point, and scores will be reported as a group.

You are free to withdraw your consent at any point without penalty. You may also request that the research destroy any of your personal data or information collected during the sessions. You should only take part in this study if you wish to be a volunteer.

You may choose not to sign this form, in which case you will not be eligible to participate in the study. There is no pressure to participate in the study, it should be voluntary. You are also free to withdraw from the study at any time.

If you have any questions or concerns, please contact Saige Hupman (*email: saige.hupman@cortland.edu, phone: 607-237-1614*) or Dr. James Hokanson (*email: james.hokanson@cortland.edu, phone: 607-753-4964*). If you have questions about your rights as a participant in this study, general questions, complaints, or concerns you would like to discuss with someone uninvolved in the research project, contact the SUNY Cortland Institutional Review Board. (*email: irb@cortland.edu, phone: 607-753-2511*).

Consent to Participate in**Effects of ankle weights on metabolic response and muscular activity at lower body positive pressure**

I willingly and freely give my consent to participate in this study. I understand that by signing this form I am agreeing to take part in research. I have received a copy of this form to keep for my own records.

I [print name] _____ have read the description of the project for which my consent is required, understand my rights as a participant, and I hereby consent to participate in this study.

Signature: _____

D.O.B. _____

Witness: _____

Date: _____

SUNY Cortland IRB
Protocol Approval Date: 2/21/2017
Protocol Expiration Date: 2/20/2018

APPENDIX C

Physical Activity Readiness Questionnaire

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(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	
<input type="checkbox"/>	<input type="checkbox"/>	1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
<input type="checkbox"/>	<input type="checkbox"/>	2. Do you feel pain in your chest when you do physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	3. In the past month, have you had chest pain when you were not doing physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	4. Do you lose your balance because of dizziness or do you ever lose consciousness?
<input type="checkbox"/>	<input type="checkbox"/>	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?
<input type="checkbox"/>	<input type="checkbox"/>	6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
<input type="checkbox"/>	<input type="checkbox"/>	7. Do you know of <u>any other reason</u> why you should not do physical activity?

If
you
answered

YES to one or more questions

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.

NO to all questions

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.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever — wait until you feel better; or
- if you are or may be pregnant — talk to your doctor before you start becoming more active.

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.

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.

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 _____

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.



© Canadian Society for Exercise Physiology www.csep.ca/forms

APPENDIX D

Participant Reminder Email

[Participant's name],

Thank you for volunteering to be a participant in my thesis project! Listed here are descriptions and instructions for testing.

You will walk and run in the AlterG® treadmill at 60% body weight (8 min total). One time you come to the lab you will walk and run without any additional weight, the other time you will walk and run with ankle weights on (1.4 lb each).

In addition to the ankle weights for one test, during both tests you will wear:

*Wireless EMG electrodes on your right leg, on the gastrocnemius, vastus medialis, and tibialis anterior muscles. Please wear shorts and sneakers so we can get the EMG electrodes in ideal position. We will prep the skin prior to putting on the electrodes by shaving if necessary.

*Heart rate monitor

*Neoprene mask to measure oxygen consumption during exercise

You are scheduled to come in to the **exercise physiology lab** at **am/pm on day, Month** and **am/ pm on day, Month**. If there is a class going on, please come in through the glass door around the corner from 1170.

Please do not consume caffeine or exercise 12 hours prior to a testing session. Please respond to this email to confirm, I will send another reminder the morning of the tests.

Thank you,

Saige

(607) 237-1614

saige.hupman@cortland.edu

APPENDIX E

Participant Data Collection Sheet

Participant: _____ ID #: _____ DOB: ___ / ___ / ___ Short size:
 _____ AG Height: _____

Condition: _____
 Weight: _____ Height: _____
 Calibration #: _____

Speed	Time	Breeze time	VO ₂ (mLO ₂ /kg/min)	R-value	HR (bpm)	RPE	Kcal
Rest	0 min						
3mph	4 min						
6mph	8 min						

Condition: _____
 Weight: _____ Height: _____
 Calibration #: _____

Speed	Time	Breeze time	VO ₂ (mLO ₂ /kg/min)	R-value	HR (bpm)	RPE	Kcal
Rest	0 min						
3mph	4 min						
6mph	8 min						

Has normalized testing been performed? Y/N

APPENDIX F

Participant Anthropometric Data with Means and Standard Deviations

Subject	Sex	Age	Height (m)	Weight (kg)
01	M	26	1.78	61.69
02	F	22	1.73	100.9
03	F	22	1.58	47.58
04	M	22	1.54	52.44
05	M	21	1.73	70.31
06	F	23	1.25	50.48
07	M	20	1.73	77.29
08	F	22	1.73	52.57
09	F	21	1.68	58.56
010	F	22	1.62	57.38
011	F	21	1.62	53.8
012	F	23	1.59	70.17
013	F	22	1.67	81.92
014	M	20	1.92	108.3
015	F	21	1.55	50.44
016	M	23	1.83	75.89
Mean		21.94	1.66	66.86
Std. Dev.		1.44	0.15	18.25