PHYSIOLOGICAL RESPONSES TO RUNNING ON A LAND AND ANTI-GRAVITY TREADMILL

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

IN THE GRADUATE SCHOOL OF THE

TEXAS WOMAN'S UNIVERSITY

SCHOOL OF HEALTH PROMOTION AND KINESIOLOGY

COLLEGE OF HEALTH SCIENCES

BY

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DENTON, TEXAS

MAY 2020

DEDICATION

To my family, Clark, CJ, and Ethan. Thank you for your never-ending love, support, and encouragement.

ACKNOWLEDGEMENTS

First, I would like to thank my husband, Clark, for his support as I worked to complete this degree, and especially as I worked to complete the dissertation. There have been countless times that he must have felt like a single father to our sons, and I am forever grateful for his assistance throughout the process.

I would like to thank my chair and advisor, Dr. David Nichols, for his guidance and mentorship throughout the degree and dissertation process. Thank you for continuing to check in with me every semester and for not giving up on me. I would like to thank Dr. Rhett Rigby and Dr. Kyle Biggerstaff for their valuable assistance and guidance.

To my colleagues at Texas A&M University – Commerce, especially Dr. Anthony Rosselli, Dr. Tara Tietjen-Smith, and Michael Oldham for their support, suggestions, and friendship throughout the process. Thank you to Dr. Greg Hulsey, PT, for allowing me to utilize his clinic, AlterG treadmill, and land treadmill for data collection. Additional thanks to all of the staff at Hulsey Therapy Services for their assistance in scheduling participants, working their patients around my data collection, and friendship along the way.

Finally, I would like to thank my parents, Dennis and Monica Marek, who taught me the value of hard work and perseverance. Thank you for instilling the importance of having faith in God and making family a priority. Though it has taken longer to complete this degree than I planned, it is finally finished.

ABSTRACT

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MAY 2020

Exercise with partial body weight support can be used when pain or injury prevents exercise with full weight bearing. The purpose of this study was to determine differences in cardiorespiratory responses between running on a land treadmill and on an anti-gravity treadmill (AGT) during 30 min of exercise followed by a run to volitional fatigue. Participants (n = 12; age = 22.0 ± 4.3 years; height = 171.3 ± 6.4 cm; weight = 68.0 ± 13.0 kg) completed a familiarization session of submaximal treadmill running, two sessions on an AGT at two different body weight percentages (70 and 90%), and a run on a land treadmill. Participants returned for three additional exercise sessions: running on a land treadmill and on an AGT at 70 and 90% body weight. Each session included a 2-min self-paced warm-up, a 30-min run at 65–70% HRR, and a run to volitional fatigue at 95–100% HRR, all at 0% grade. Heart rate, oxygen consumption, energy expenditure, time to volitional fatigue, and other metabolic variables were measured. A one-way repeated measures ANOVA was used to determine differences in HR, VO_2, EE, and TTE during each condition. Time to reach volitional fatigue was seven times greater for the 70% body weight and three times greater for the 90% body weight conditions on the AGT

compared to the land treadmill condition. At 30 min of exercise, EE and VO_2 during the 70 and 90% conditions on the AGT were less when compared to the land treadmill condition ($p < .05$), while HR during the 70% condition was less than 90% condition on the AGT ($p = .013$) and the land treadmill condition ($p = .001$). At volitional fatigue, HR was lower during the 70% condition compared to 90% condition on the AGT ($p = .046$), and VO_2 was lower during the 70% condition on the AGT compared to the land treadmill condition ($p = .005$). Running with body weight support on the AGT may reduce metabolic demand. Increasing intensity or duration may allow for HR and VO_2 responses to reach targeted levels during specific body weight support conditions.

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CHAPTER I

INTRODUCTION

The use of partial body weight support during walking or running can be a valuable rehabilitation tool when individuals are unable to exercise at full weight bearing capacity due to injury or pain. Three methods commonly used to reduce weight bearing status during exercise include water immersion or hydrotherapy, a harness support system, or an anti-gravity treadmill (AGT). Hydrotherapy allows for a decrease in weight bearing status during exercise. However, the resistance of the water can alter joint kinematics and walking velocity (Miyoshi, Shirota, Yamamoto, Nakazawa, & Akai, 2004; Patil et al., 2013).

Conversely, the harness system has been shown to support body weight during exercise without altering body kinematics (Ruckstuhl, Kho, Weed, Wilkinson, & Hargens, 2009). Spatiotemporal parameters of gait (e.g., cadence and stride length), and lower body kinematics (e.g., angle of hip, knee and ankle) at heel strike were unchanged when participants walked on a treadmill with the assistance of a harness system that decreased their body weight loading to 66 and 33% body weight when compared to lower body positive pressure treadmill running (Ruckstuhl et al., 2009). Disadvantages of the harness system include discomfort, respiratory restrictions, and movement restriction of the arms and legs (Hoffman & Donaghe, 2011; Raffalt, Hovgaard-Hansen, & Jensen, 2013; Ruckstuhl et al., 2009).

An AGT utilizes air pressure to reduce the weight bearing capacity of the individual (Figueroa, Manning, & Escamilla, 2011; Ruckstuhl et al., 2009). The AGT can provide varying levels of unweighting of the participant to effectively reduce the load on the lower extremity, while maintaining normal gait kinematics, range-of-motion, and comfortability for the participant (Berthelsen et al., 2014; Raffalt et al., 2013; Ruckstuhl et al., 2009).

The use of an AGT as an exercise tool may be beneficial for a variety of populations, such as those with musculoskeletal disorders. In a study by Takacs, Anderson, Leiter, MacDonald, and Peeler (2013), participants with knee osteoarthritis completed two bouts of exercise on an AGT. The participants reported significant decreases in pain during the exercise sessions, while feeling safe and confident (Takacs et al., 2013). Berthelsen et al. (2014) reported an increase in walking distance of 8% and improved dynamic postural control by 13% in adult participants diagnosed with muscular dystrophy after 10 weeks of exercising 3 times per week for 20 min on an AGT. Children diagnosed with cerebral palsy improved balance, strength, and walking performance following 6 weeks of AGT training performed 2 days per week for 30 min (Kurz, Corr, Stuberg, Volkman, & Smith, 2011). In healthy athletes, higher running speeds at maximal intensities may be achieved on an AGT when compared to a standard land treadmill (Gojanovic, Cutti, Shultz, & Matheson, 2012).

Physiological responses have been assessed at varying levels of weight bearing status using an AGT. In a study by Figueroa et al. (2011), no significant differences in maximal oxygen consumption (VO_2 max), heart rate (HR), or respiratory exchange ratio (RER) were reported at 100, 90, and 80% of body weight on an AGT. Participants attained similar VO_2 max values on a land treadmill and on an AGT at 100, 95, 90, and 85% of body weight, while achieving faster speeds on an AGT (Gojanovic et al., 2012). While ground reaction forces are reduced in proportion to the removal of body weight, the HR and VO_2 responses may not be affected by the level of body weight support (Hoffman & Donaghe, 2011). Raffalt et al. (2013) compared the results of graded exercise testing protocols at a maximal intensity on a land treadmill and on an AGT at 100% body weight, and found similar values for VO_2 max, HR, rating of perceived exertion (RPE), and concentration of blood lactate. In the same study, participants completed 3-min bouts at 2.78, 3.89, and 5 m/s for each 100, 75, 50, and 25% of their body weight (Raffalt et al., 2013). As body weight decreased, HR, VO_2, pulmonary ventilation (V_E), RPE, and both peak and mean ground reaction forces decreased (Raffalt et al., 2013). All variables increased in magnitude as speed increased for any given body weight condition (Raffalt et al., 2013). In another study, participants walked on an AGT at three velocities (i.e., 1.0, 1.25, and 1.5 m/s) at each of five body weight percentages (i.e., 25, 50, 75, 85, and 100%) for 7 min with 3 min of rest between each trial over two sessions (Grabowski, 2010). Complementing the results of previous studies, ground reaction forces decreased as body weight decreased, and increased as velocity increased (Grabowski, 2010). Metabolic power also decreased as body weight percentage decreased, and increased as velocity increased (Grabowski, 2010). Additional studies had participants exercise for 4 and 5 min bouts at different speeds and body weight percentages, and a proportional decrease in VO_2 and HR with body weight percentage, was reported (McNeill, de Heer, Williams, & Coast, 2015; McNeill, Kline, de Heer, & Coast, 2015).

The differences in physiological measures while exercising on a land treadmill and on an AGT have been reported in previous studies (Figueroa et al., 2011; Gojanovic et al., 2012; Grabowski, 2010; Hoffman & Donaghe, 2011; McNeill, de Heer, Williams, et al., 2015; McNeill, Kline, et al., 2015; Raffalt et al., 2013). The protocols in these studies have included maximal graded exercise tests or short bouts (i.e., 3–7 min) of running or walking. Physiological measures during longer bouts of exercise on an AGT have not been well characterized. The purpose of this study was to determine cardiorespiratory differences between running on a land treadmill and on an AGT during 30 min of exercise followed by a run to volitional fatigue. Specifically, this study determined differences in energy expenditure (EE; total kcal), VO_2, time to volitional fatigue (TTE), HR, RER, blood lactate, and RPE.

Hypotheses/Research Questions

The research question was to determine differences in total EE (kcal), oxygen consumption (VO_2), TTE, HR, RER, blood lactate (mmol/L), and RPE when running on an AGT compared to a land treadmill. The research hypotheses were (1) AGT conditions will have increased values for TTE compared to the land treadmill, and (2) AGT conditions will have a decreased EE, VO_2, HR, RER, blood lactate, and RPE compared to the land treadmill.

Limitations/Delimitations

The limitations of this study included participant selection, psychological effects, and participant training. Participants were recruited from a college campus and the community. Due to the nature of the study, it was expected that participants had an interest in fitness and exercise. This may have affected the results, especially if the participants had prior knowledge of aspects of the exercise science discipline. Psychological effects may have occurred if participants had previous experience with, or knowledge of, the AGT. Participants may have exerted more or less effort based on their experience. It was expected that participants were experienced runners who ran a minimum of 3 times each week, completing a minimum of 15 miles/week for the last 6 months. The level of running experience and quantity of running completed each week varied between participants, which may have affected the results. Participants were expected to refrain from strenuous exercise 24 hr before each exercise session. The delimitations of this study were normal, healthy, male and female participants between the ages of 18 and 45 years who had not experienced musculoskeletal injury in the past 6 months. Participants were physically active as previously described and were be able to successfully complete all exercise sessions for the study.

Definitions

<u>Anti-gravity treadmill</u> (AGT) – a treadmill system that reduces weight bearing status during running by utilizing air pressure. The Alter-G treadmill is the most commonly used device to alter body weight characteristics while performing aerobic exercise, and is often referred to as a lower body positive pressure treadmill.

<u>Maximal Oxygen Consumption</u> (VO_2 max) – the greatest amount of oxygen uptake by the body during high-intensity exercise, with relative values expressed in ml/kg/min (McArdle, Katch, & Katch, 2010; Powers & Howley, 2018).

<u>Submaximal Oxygen Consumption</u> – the amount of oxygen uptake by the body during exercise at a submaximal intensity which can be used to estimate VO_2 max, with, relative values expressed in ml/kg/min.

<u>Time to volitional fatigue</u> (TTE) – the amount of time a participant can run at 95 to 100% HRR until volitional fatigue or exhaustion prevents them from maintaining pace with the treadmill, or the participant places hands on the treadmill to maintain balance. For the purposes of this study, the abbreviation TTE will be used to indicate time to volitional fatigue.

<u>Caloric expenditure</u> – the number of calories used by the body during the exercise session measured through indirect calorimetry, also referred to as total energy expenditure (EE) and measured in kcal.

<u>Heart Rate Reserve</u> (HRR) – a method to estimate exercise intensity based on the formula [((220 – age) – resting HR) x % intensity] + resting HR (Pescatello, 2014).

Significance of the Study

This study provided information regarding the potential value of the AGT for athletes who need to maintain or improve their cardiovascular endurance while they are not able to exercise in a full weight bearing capacity. This would apply mostly in a rehabilitative setting where athletes may be experiencing pain or have an injury that limits their ability to exercise during full weight bearing. The limited research on the AGT thus far has evaluated only short-term exercise completed at the same intensity (McNeill, Kline, et al., 2015; Raffalt et al., 2013) or variable intensity, short-term exercise (Gojanovic et al., 2012). Thus, it remains unknown if the longer duration exercise typically used for endurance training would elicit the same physiological responses during weight supported exercise on a treadmill as compared to more traditional treadmill exercise.

CHAPTER II

LITERATURE REVIEW

Introduction

Aerobic exercise using an AGT may be beneficial for individuals with a chronic injury, pain, or diagnosed musculoskeletal disorder (Berthelsen et al., 2014; Gojanovic et al., 2012; Kurz et al., 2011; Ruckstuhl et al., 2009; Takacs et al., 2013). Other methods used to reduce body weight support during exercise include a harness system and water immersion. However, using a harness system may lead to discomfort, respiratory restrictions, and restricted arm and leg movements in the participant (Hoffman & Donaghe, 2011; Raffalt et al., 2013). There are also concerns with water immersion, which can lead to altered gait kinematics and muscle activation patterns due to the buoyancy and resistance supplied by the water (Figueroa et al., 2011; Hoffman & Donaghe, 2011; Miyoshi et al., 2004). The AGT may be the preferred method of decreasing body weight during exercise because it can reduce ground reaction forces, elicit high levels of cardiorespiratory stress, and provide unrestricted movement (Figueroa et al., 2011; Gojanovic et al., 2012; Grabowski, 2010; Hoffman & Donaghe, 2011; Patil et al., 2013; Raffalt et al., 2013). The purpose of this study was to determine differences in cardiorespiratory responses between running on a land treadmill and an AGT at two levels of weight bearing status during 30 min of exercise followed by a run to volitional fatigue. Specifically, differences in EE, TTE, HR, RER, blood lactate, and RPE were characterized.

The following literature review will evaluate the existing research related to the physiological responses to different modes of exercise. Specifically, the responses to exercise using varying weight support will be summarized. The literature search process began by using the universal search tool on the library's website. Keywords used in the search for weight bearing support included anti-gravity treadmill, AlterG treadmill, lower body positive pressure treadmill, and reduced gravitational load running. Specific databases were also searched using the same keywords in SPORTDiscus, PubMed, and Academic Search Complete. After reviewing the journal articles retrieved through this search process, many of the sources cited in those articles seemed to be valuable. The reference list of each article was reviewed to identify supportive research. Those citations were located using the library's databases. Additionally, AlterG, Inc. compiles a list of clinical research that has been completed using the AlterG treadmill. This list of research was reviewed to identify relevant articles.

Physiological Responses to Exercise

As an individual begins to exercise, adjustments in the cardiovascular system are made nearly immediately at the onset of exercise to allow the working muscles to continue to function (De Cort, Innes, Barstow, & Guz, 1991; Williamson, Fadel, & Mitchell, 2006). With the onset of exercise, central command initiates the adjustments in the cardiovascular system, followed by influence of the arterial baroreceptor reflex and exercise pressor reflex (Williamson et al., 2006). Feedback from these reflexes will influence sympathetic and parasympathetic nerve activity causing changes to HR, stroke volume, and mean arterial pressure (Williamson et al., 2006). As skeletal muscle activity occurs with exercise, baroreceptors in the arteries provide feedback to the arterial baroreceptor reflex, while mechanoreceptors and chemoreceptors in the muscles, heart, carotid arteries, and aortic arch provide feedback to the exercise pressor reflex (Powers & Howley, 2018; Williamson et al., 2006). Increased activity in the sympathetic nervous system causes increased HR (Rowell, 1993; Williamson et al., 2006). Skeletal muscle activity increases venous return of blood to the heart, which increases stroke volume (Rowell, 1993; Williamson et al., 2006). Additionally, as HR and stroke volume increase, cardiac output increases, leading to increased blood flow to the working skeletal muscles (Powers & Howley, 2018; Rowell, 1993). Though central command initiates these processes with the onset of exercise, feedback from all areas of the body work to meet the metabolic demands during exercise (Williamson et al., 2006).

Metabolic rate during exercise is measured as oxygen consumption or VO_2 using the Fick equation: $VO_2 = Q \times [a\text{-}v]O_2$ difference, defined as cardiac output times arteriovenous oxygen difference (Powers & Howley, 2018; Rowell, 1993). Hill and Lupton (1923) assessed VO_2 while participants ran on a level surface at constant speeds of 3.02, 3.38, and 4.45 m/s. Oxygen consumption increased with the onset of exercise and reached its peak level at approximately 150 s of exercise while maintaining constant speed (Hill & Lupton, 1923). Additionally, participants achieved higher VO_2 levels when constant running speed changed from 3.02 to 3.38 to 4.45 m/s (Hill & Lupton, 1923). Similarly, Taylor, Buskirk, and Henschel (1955) reported VO_2 increased as speed increased from 3.58 to 4.92 m/s when grade was 0%. As treadmill grade increased in 2.5% intervals from 0–12.5% while running at 3.13 m/s, VO_2 increased as well. Taylor et al. (1955) suggested VO_2 is affected by the amount of muscles that are utilized during exercise after having participants run at 3.13 m/s at 9, 11, and 13% grade, with and without arm exercise. The addition of arm exercise resulted in a 0.2 L/min increase in VO_2 compared to running without arm exercise (Taylor et al., 1955).

De Cort et al. (1991) utilized a cycling protocol to assess the relative contribution of cardiac output associated with increases in VO_2 during exercise. Participants cycled for 4 min without resistance followed by an abrupt increase in load of 70 W in females and 80 W in males, which was maintained for 4 min. Within 3 s of the sudden increase in load, cardiac output increased mostly due to the increase in HR, but partially due to the increase in stroke volume of 13 ± 9 ml (De Cort et al., 1991). However, arteriovenous oxygen difference contributed to the increased VO_2 as exercise continued for the 4-min bout (De Cort et al., 1991). Systolic blood pressure increased with exercise, but the increase occurred at a slower rate compared to cardiac output and VO_2 possibly due to the vasodilation in the exercising muscles (De Cort et al., 1991).

Metabolic and blood lactate responses were evaluated by having trained runners complete five trials of running for 5 min at six speeds ranging from 4.44–5.59 m/s (Costill, 1970). Resting blood lactate level was 9.2 mg/dl, and while running at speeds of

4.72 m/s or less, blood lactate remained near the resting level (Costill, 1970). However, blood lactate rapidly increased when running speed increased beyond 4.72 m/s, which was associated with approximately 70% aerobic capacity (Costill, 1970). Additionally, participants completed a 10-km run to exhaustion at a speed equivalent to the participant's best 10-km race pace (Costill, 1970). Participants tolerated exercise at 85–98% VO_2 max for the last 25 min of the run as part of the run to exhaustion. Ventilation, HR, and VO_2 increased during the run and reached near maximal levels at the conclusion of the run, while blood lactate levels were relatively low at 33.4–44.9 mg/dl (Costill, 1970). Costill (1970) suggested highly trained runners may be able to exercise at higher intensities without blood lactate accumulating extensively.

In summary, there is a linear relationship between HR, VO_2, cardiac output, blood pressure, and ventilation as workload increases during exercise (Costill, 1970; De Cort et al., 1991; Hill & Lupton, 1923; Taylor et al., 1955; Williamson et al., 2006). Initial increases in VO_2 may be due to increases in HR and stroke volume, but as exercise continues, arteriovenous oxygen difference contributes to the rise in VO_2 as well (De Cort et al., 1991). There is a maximum level of VO_2 that can be obtained during exercise, which is observed as a plateau in VO_2 even though workload continues to increase with exercise (Costill, 1970; Hill & Lupton, 1923; Taylor et al., 1955).

Responses of Outcome Variables with Traditional Exercise: Treadmill, Bike, Elliptical

Various modes of exercise are often used in exercise testing or prescriptions such as the treadmill, stationary cycle, or elliptical. Mays, Boér, Mealey, Kim, and Goss (2010) compared HR and VO_2 responses to exercise on a treadmill, cycle, and elliptical. Participants completed incremental exercise tests to reach exhaustion on each device. The cycle elicited lower VO_2 peak (36.33 ml/kg/min, $p < .001$) compared to the treadmill (47.8 ml/kg/min) and the elliptical (48.7 ml/kg/min; Mays et al., 2010). Additionally, HR max was lower on the cycle (185.1 bpm) compared to the age predicted HR max (198.1 bpm) on the treadmill (196.7 bpm; $p < .001$; Mays et al., 2010). Similarly, Crommett, Kravitz, Wongsathikun, and Kemerly (1999) had participants exercise at a self-selected intensity for 6 min on a treadmill, elliptical with legs only, and elliptical with both arms and legs. No differences were observed for VO_2, but when exercising on the elliptical while using both arms and legs, responses were higher for ventilation (55.63 vs 49.09 and 47.63 L/min), HR (176.8 vs 172.5 and 167.6 bpm), and RPE (14.6 vs 13.3 and 13.1; $p < .05$) compared to the elliptical with legs only and the treadmill (Crommett et al., 1999). Porcari, Zedaker, Naser, and Miller (1998) had participants exercise at a self-selected pace for 20 min on an elliptical, treadmill walking, treadmill running, cycling, and stepping. The elliptical and treadmill running responses for VO_2, HR, and caloric expenditure were not different ($p > .05$); however, responses were greater on the elliptical (32.9 ml/kg/min; 157 bpm; 11.9 kcal/min; $p < .05$) than treadmill walking (21.5

ml/kg/min; 127 bpm; 7.6 kcal/min), cycling (26.1 ml/kg/min; 145 bpm; 9.4 kcal/min), and stepping (28.8 ml/kg/min; 152 bpm; 10.8 kcal/min; Porcari et al., 1998). Chester et al. (2016) compared metabolic cost on a standard elliptical, lateral elliptical, and treadmill. Participants exercised for 10 min on each device at an intensity to elicit an RPE of 11–14 using the Borg scale, and achieved steady state within approximately 3 min of exercise. Caloric expenditure and VO_2 were greater for the lateral elliptical (12.0 kcal; 36.7 ml/kg/min) and treadmill (11.7 kcal; 35.7 ml/kg/min) compared to the standard elliptical (8.3 kcal; 26.1 ml/kg/min; $p < .001$). However, RER was lower on the standard elliptical (0.87; $p < .001$) and treadmill (0.87; $p = .002$) compared to the lateral elliptical (0.94; Chester et al., 2016).

When comparing a cycle ergometer to treadmill running during an incremental test to volitional exhaustion, VO_2 peak was greater for treadmill running (47.7 ml/kg/min) compared to cycling (44.4 ml/kg/min; $p < .05$; Carter & Dekerle, 2014). Participants also completed an exercise bout to exhaustion at critical speed and critical power on the treadmill and cycle ergometer (Carter & Dekerle, 2014). At exhaustion, no differences were observed between conditions for blood lactate, VO_2, and time to reach exhaustion (Carter & Dekerle, 2014). In contrast, Fontana, Boutellier, and Knopfli-Lenzin (2009) compared exercise on a treadmill to a cycle ergometer while participants exercised at maximal lactate steady state, which was defined as the intensity required to maintain blood lactate within 1 mmol/L while exercising at a constant load for 30 min (Fontana et al., 2009). Responses for ventilation, HR, and VO_2 were lower during cycling

(93 l/min; 165 bpm; 3.1 l/min) compared to treadmill running (103 l/min; 175 bpm; 3.4 l/min; $p < .01$). Blood lactate was higher during cycling (5.6 mmol/L) compared to treadmill running (4.3 mmol/L; $p < .01$); however, no differences were observed between conditions for the time to reach exhaustion (Fontana et al., 2009).

Similar cardiorespiratory responses during exercise on a treadmill and elliptical have been measured in other studies (Chester et al., 2016; Crommett et al., 1999; Mays et al., 2010; Porcari et al., 1998). In these studies, cycling exercise elicited lower responses compared to the treadmill (Fontana et al., 2009) and elliptical (Mays et al., 2010; Porcari et al., 1998). Some differences in the responses to exercise on the elliptical may be related to the type of elliptical utilized for the exercise bout (Chester et al., 2016). The elliptical and treadmill elicited similar cardiorespiratory responses suggesting these modes of exercise could be used interchangeably in exercise testing and prescription (Mays et al., 2010).

Introduction to AGT

The AlterG Anti-Gravity Treadmill (Fremont, CA) is a treadmill system that utilizes differential air pressure to support the body weight of individuals while they exercise. It is typically referred to as an AGT or as a lower body positive pressure treadmill. Participants wear neoprene shorts that zip at the waist to the airtight pressure chamber of the AGT. The air pressure inside the chamber can be increased or decreased to support up to 80% of the body weight of the individual with 1% body weight increments (*AlterG Anti-Gravity Treadmill M320/F320 Operation Manual*, 2015). The treadmill speed can be adjusted 0–5.4 m/s and incline can be increased up to 15% (*AlterG Anti-Gravity Treadmill M320/F320 Operation Manual*, 2015). The concept of the AlterG was developed in the 1960s by NASA to allow astronauts to exercise in space by using air pressure to hold the astronauts down on the treadmill (Gillis, 2015). However, at this point, the primary purpose of the pressure chamber was to add gravity to the chamber and increase the level of weight bearing for the individual (Gillis, 2015). Years later, the concept was adapted to reduce gravity using the air pressure chamber and to allow individuals to run in a partial weight bearing state. In 2005, the first working prototype of the AlterG was created, and the first model was sold in 2007 (Gillis, 2015).

The accuracy of the amount of body weight support provided by the AGT has been evaluated to determine the levels of body weight support that is most accurate (Hoffman & Donaghe, 2011; McNeill, de Heer, Bounds, & Coast, 2015). Hoffman and Donaghe (2011) evaluated actual body weight on the AGT with 100, 75, and 50% weight bearing, and observed approximately 5% difference between actual body weight and settings on the AGT (100% AGT: 95 ± 2%; 75% AGT: 70 ± 2%; and 50% AGT: 45 ± 4%). Additionally, McNeill, de Heer, Bounds, et al. (2015) evaluated the accuracy of the body weight support provided by the AGT at 10% increments from 100–20% body weight. At 100% AGT, body weight was evaluated both with the AGT chamber inflated and deflated. For 100% AGT with the chamber deflated, body weight was accurate, but with the chamber inflated, body weight was actually 93.15% ($p < .001$), indicating the air in the chamber provided some support when the AGT was set at 100% weight bearing

(McNeill, de Heer, Bounds, et al., 2015). The level of weight bearing support provided when the AGT was set at 90, 80, and 70% was accurate; however, at 60–20% body weight, the AGT provided 2–7% ($p < .001$) less support than expected (McNeill, de Heer, Bounds, et al., 2015). The degree of inaccuracy increased as the body weight support from the AGT increased. When the AGT was set at 60% body weight, actual body weight was 61.95%, and 20% body weight was actually 27.67% (McNeill, de Heer, Bounds, et al., 2015).

Body Weight Support During Exercise

Harness Support System

A harness support system has been used with a land treadmill to allow individuals to exercise with body weight support. Ruckstuhl et al. (2009) evaluated gait parameters, HR, and comfort level of participants while they exercised on a lower body positive pressure treadmill and a harness support system for a land treadmill. Participants exercised with both body weight support systems at 100, 66, and 33% body weight at three speeds to simulate slow walking, comfortable walking, and walk-run transition. Both body weight support systems resulted in decreased cadence, stride length, and HR as body weight support increased (Ruckstuhl et al., 2009). There were no differences between support systems for cadence and stride length; however, HR was 4% lower ($p < .05$) and comfort level was 24% higher ($p < .001$) for the lower body positive pressure treadmill compared to the harness support system (Ruckstuhl et al., 2009). The harness system caused more discomfort as the level of body weight support increased, and the lower body positive pressure treadmill system caused participants to feel that their arm motions were restricted due to the pressure chamber (Ruckstuhl et al., 2009).

Another study had participants run at 3 m/s with 75, 50, and 25% body weight using a harness system with a fixed pulley and a rolling trolley (Teunissen, Grabowski, & Kram, 2007). For both harness systems compared to normal running, net metabolic rate decreased 19, 38 and 55% as body weight support increased from 75% body weight to 50 and 25% body weight ($p < .0001$; Teunissen et al., 2007). Additionally, peak vertical and horizontal ground reaction forces decreased 40–47% ($p < .05$) as body weight support increased (Teunissen et al., 2007). Aaslund and Moe-Nilssen (2008) evaluated effects of a harness system while walking overground and on a land treadmill. When walking overground, no differences were observed in anterioposterior and mediolateral acceleration or in cadence when not wearing the harness support system compared to wearing the harness (Aaslund & Moe-Nilssen, 2008). However, when running at 70% body weight with the harness support system, vertical and anterioposterior forces decreased and mediolateral forces increased compared to the land treadmill (Aaslund & Moe-Nilssen, 2008).

Colby, Kirkendall, and Bruzga (1999) evaluated muscle activity and oxygen consumption while using a harness system to provide body weight support during exercise. Participants walked on a treadmill at 1.34 m/s and 0% grade with 100, 80, and 60% weight bearing. Electromyography for the quadriceps decreased 27.2% ($p < .05$) at 60% weight bearing compared to full weight bearing, but no other differences were observed at 60 or 80% weight bearing (Colby et al., 1999). Time to reach peak electromyography amplitude was later for the rectus femoris ($p < .05$) at 80% body weight, but no differences were observed for the other conditions. Additionally, VO_2 decreased 6% with 80% body weight and 12% with 60% body weight compared to full weight bearing (Colby et al., 1999). Use of a harness support system may allow individuals with lower extremity injuries to exercise with body weight support while maintaining normal muscle activation patterns; however, metabolic demand may be decreased as well (Colby et al., 1999).

A study by Threlkeld, Cooper, Monger, Craven, and Haupt (2003) evaluated lower extremity kinematic factors during five levels of body weight support using a harness system. Participants walked at 1.25 m/s on a land treadmill with a harness support system for 1–3 min at 90, 70, 50, and 30% body weight. Participants also completed a trial at minimal body weight support where the support straps for the harness system were tightened enough to remove the slack; however, there was no difference in any variable between this trial and the 90% body weight trail. At 90% body weight, cadence decreased 2.3 steps/min ($p < .01$) and stride length increased 1.7 cm ($p < .01$) compared to 30 and 50% body weight (Threlkeld et al., 2003). As weight bearing decreased from 90 to 30%, total stance phase (64.1 vs. 60.1%) and double limb support phase (14.1 vs. 9.8%) decreased (Threlkeld et al., 2003). Limiting the amount of body weight support during exercise may help retain normal gait mechanics (Threlkeld et al., 2003).

Water Immersion

Water immersion exercise, such as aquatic treadmill exercise, water walking, and deep-water running, can be used to provide body weight support during exercise. An aquatic treadmill or underwater treadmill is a treadmill that is specifically designed to be used in a swimming pool. Water walking consists of walking in a pool at various water depths while allowing the person to be in contact with the pool's floor. Deep-water running consists of mimicking the running action while the body is fully supported by water in the deep end of a swimming pool. Runners wear a floatation device to help them maintain their position in the water while their feet do not come into contact with the pool's floor.

Macdermid, Wharton, Schill, and Fink (2017) had participants run on an aquatic treadmill at 2.61 m/s for 3 min at three water depths: mid-shin, mid-thigh, and xiphoid process. Stride frequency was greater for mid-shin (1.420 Hz) and for mid-thigh (1.237 Hz) compared to the xiphoid process (1.13 Hz; $p < .05$). Stride length was lower for mid-shin depth (1.933 m) compared to the mid-thigh depth (2.128 m) and xiphoid process depth (2.349 m; $p < .05$). Ground contact time was lower for mid-shin depth (214.5 s) compared to the xiphoid process depth (263.6 s), and swing time was lower for mid-shin depth (530 s) compared to the xiphoid process depth (625.1 s; $p < 0.5$). Additionally, HR was lower for xiphoid process depth (145 bpm) compared to mid-shin depth (174 bpm; $p < .05$) and mid-thigh depth (173 bpm; $p < .01$; Macdermid et al., 2017).

Brubaker, Ozemek, Gonzalez, Wiley, and Collins (2011) compared cardiorespiratory responses on an aquatic treadmill and a land treadmill. Participants completed 2-min stages that consisted of running at 0.64, 1.36, 2.03, and 2.67 m/s at 0% grade on each device. The last three stages were at 2.67 m/s with 1, 2, and 4% incline on the land treadmill, and 30, 40, and 50% jet velocity on the aquatic treadmill. No differences were observed between the aquatic and land treadmills for HR, RPE, and ventilation for any of the stages. For Stage 3 (2.03 m/s, 0% incline), VO_2 was 12% lower ($p < .05$) on the aquatic treadmill compared to the land treadmill (Brubaker et al., 2011). For all stages, HR and VO_2 had a positive linear relationship that was similar between the aquatic treadmill ($r = .94$) and the land treadmill ($r = .95$; Brubaker et al., 2011). Similarly, Silvers, Rutledge, and Dolny (2007) compared cardiorespiratory responses on an aquatic treadmill to a land treadmill while completing an incremental exercise test to volitional exhaustion. On the land treadmill, grade was 0% while speed was increased 0.22 m/s every minute until participants reached a maximum speed of 4.42 m/s, then grade was increased 2% every minute until volitional exhaustion was reached. On the aquatic treadmill at a depth of the xiphoid process, jet resistance was set at 40% while speed increased 0.22 m/s every minute until participants reached a maximum speed of 3.45 m/s, then jet resistance was increased 10% each minute until volitional exhaustion was reached. No differences between the aquatic and land treadmills were observed for VO_2, HR, RER, RPE, test time, final speed, lactate, and tidal volume (Silvers et al., 2007). Minute ventilation and breathing frequency was significantly lower on the land treadmill (124.4 L/min; 50.0 breaths per min) compared to the aquatic treadmill (135.2 L/min; 55.3 breaths per min; $p < .001$; Silvers et al., 2007).

Cardiorespiratory responses on an aquatic treadmill were compared to a land treadmill while completing 3-min incremental exercise stages at 0.89, 1.34, 1.79, 2.23, 2.68, and 3.13 m/s (Greene, Greene, Carbuhn, Green, & Crouse, 2011). Participants completed this on the land treadmill and on the aquatic treadmill in chest-deep water with jet resistance set to 0, 25, 50, 75, and 100%. No differences were observed between conditions for VO_2 max, minute ventilation, and RPE. However, HR and RER were lower on the aquatic treadmill (HR: 167 bpm; RER: 1.04) compared to the land treadmill (HR: 171 bpm; RER: 1.20; $p < .001$; Greene et al., 2011). Except for the 1.34 m/s stage, VO_2 was lower for the 0% and 25% jet resistance compared to the land treadmill, but at 100% jet resistance VO_2 was 134% higher compared to the land treadmill (Greene et al., 2011). When running speed was above 1.34 m/s, HR was lower at 0 and 25% jet resistance on the aquatic treadmill compared to the land treadmill, but was greater at 75 and 100% jet resistance on the aquatic treadmill (Greene et al., 2011).

Rutledge, Silvers, and Browder (2007) assessed metabolic cost on an aquatic and land treadmill. Participants completed nine, 5 min trials on the aquatic treadmill at 2.9, 3.35, and 3.8 m/s with 0, 50, and 75% jet resistance. For the land treadmill, participants began running at a preselected speed for 2 min, followed by incremental speed increases of 0.11 m/s every 2 min until they reached a VO_2 level similar to each of the trials on the aquatic treadmill. No differences were observed for VO_2 for the aquatic treadmill with

0% jet resistance compared to the land treadmill condition; however, the land treadmill required greater speeds to elicit similar VO_2 responses for 50 and 75% jet resistance ($p < .05$). On the aquatic treadmill, as running speed and jet resistance increased, VO_2, HR, ventilation, pulse oximetry, and RPE also increased ($p < .01$; Rutledge et al., 2007). Brubaker et al. (2011), Greene et al. (2011), Rutledge et al. (2007), and Silvers et al. (2007) have suggested the aquatic treadmill may be able to produce similar cardiorespiratory responses to that of the land treadmill. However, it may be necessary to increase jet resistance or speed on the aquatic treadmill in order to reach similar VO_2 and HR responses to that of the land treadmill (Greene et al., 2011; Rutledge et al., 2007).

Water immersion walking was evaluated while participants walked through water in a pool that was the depth of the axilla (20% weight bearing). This condition was compared to walking on land (Miyoshi et al., 2004). Participants walked at three speeds: comfortable speed, slower than the comfortable speed, and faster than the comfortable speed. Anterioposterior ground reaction forces increased as speed increased for both land walking ($p < .05$) and water walking ($p < .01$). Additionally, anterioposterior ground reaction forces were greater during the fast water walking speed compared to the other conditions ($p < .01$). The range-of-motion of the knee was lower ($p < .01$) in water walking compared to land walking, while range-of-motion at the hip was greater ($p < .01$) for fast water walking compared to the other conditions. As water walking speed increased, peak hip flexion increased ($p < .05$), and mean electromyography amplitude (μV) from the medial gastrocnemius ($p < .05$) and biceps femoris ($p < .01$) increased. No mean electromyographic amplitude changes were observed for the land walking speeds, but the mean electromyrgraphic amplitude for the biceps femoris was greater for water walking compared to land walking. Vertical ground reaction forces decreased for the stance phase while water walking compared to land walking, suggesting buoyancy from the water may reduce impact forces while walking (Miyoshi et al., 2004).

Svedenhag and Seger (1992) evaluated cardiorespiratory responses to running on land and deep-water running. Participants completed four, 4-min bouts of deep water running where they ran with a floatation vest in the deep end of a swimming pool. Exercise intensity was based on the speed needed to reach HR values of 115, 130, 145, and 155–160 bpm during deep-water running. For the land treadmill condition, participants completed four, 4-min bouts of running at the speed needed to reach similar VO_2 levels from the deep water running stages. Average speed was 3.11, 3.61, 4.14, 4.5 m/s for the land treadmill bouts. After the submaximal exercise bouts, participants completed a maximal exercise test. Deep-water running reduced VO_2 by 12% ($p < .01$) and HR response by 9% ($p < .01$) compared to the land treadmill. Additionally, RPE and RER were greater in the deep water running condition (RPE: 14.6; RPE: 1.2) compared to the land treadmill condition (RPE: 12.6; RER: 1.1; $p < .01$; Svedenhag & Seger, 1992). At the end of the maximal run, blood lactate was higher for the deep water run than for the land treadmill run (12.4 vs 10.1 mmol/L; Svedenhag & Seger, 1992). With deep-water running, there is not a stance phase of the gait cycle, which reduces muscle activation and the metabolic cost of exercise (Svedenhag & Seger, 1992).

Two types of deep-water running, high-knees and cross-country, were compared to land treadmill running to determine biomechanical differences in the techniques (Killgore, Wilcox, Caster, & Wood, 2006). The high-knees running was similar to stair stepping, while the cross-country running was more like treadmill running. Both techniques were completed in a 3.96-m deep pool where the participants' feet did not touch the bottom, and participants wore a jogging belt floatation device. Participants completed a VO_2 max test on the land treadmill, and a 6-min run at 60% VO_2 max to obtain biomechanical data. The deep water running trials for both high-knees and cross-country running included a 6-min run at 60% VO_2 max with verbal feedback provided to the runner to assist them in maintaining the desired intensity. No differences were observed for HR and VO_2 between the conditions. Rating of perceived exertion was 1.6–1.7 higher ($p < .001$) during deep-water running compared to the land treadmill, but no differences were observed between the two types of deep-water running (Killgore et al., 2006). Stride rate was different between conditions, with cross-country running lower than both high-knees running and land treadmill running, and high-knees running lower than the land treadmill running (0.81 < 1.14 < 1.25 Hz; $p < .001$; Killgore et al., 2006). Various biomechanical differences were observed between conditions. When comparing high-knees deep-water running to land treadmill running, differences were observed in knee and ankle horizontal and vertical forces ($p = .019$). However, when comparing cross-country deep-water running to land treadmill running, similarities were observed for knee and ankle horizontal and vertical forces ($p = .019$). Killgore et al. (2006)

suggested that cross-country deep-water running may be better when the goal is having similar biomechanical factors to land treadmill running; however, either type of deep-water running may provide cardiorespiratory benefits similar to land treadmill running.

In summary, the use of a harness system and water immersion techniques to reduce weight-bearing status during exercise may alter biomechanical factors during running while providing similar cardiorespiratory benefits. The use of an AGT may provide an alternative method to allow individuals to exercise in a partial weight bearing capacity. The following sections will summarize current research evaluating the cardiorespiratory and biomechanical effects of exercise on an AGT.

Physiological Responses to AGT

Cardiovascular Responses

Similar VO_2 max values can be obtained on a land treadmill and on an AGT regardless of the amount of body weight support. Figueroa et al. (2011) had participants complete a modified Bruce protocol graded exercise test on an AGT at 100, 90, and 80% body weight. There were no significant differences (p = .99) in the VO_2 max values at each body weight condition (42 ± 8 ml/kg/min at 100%; 43 ± 9 ml/kg/min at 90%; 42 ± 7 ml/kg/min at 80% [Figueroa et al., 2011]). The time required to reach VO_2 max was not significantly different (p = .08), but there was a trend towards an inverse relationship between body weight percentage and VO_2 max with 100% body weight taking 15.5 ± 3.7 min and 80% body weight taking 21.1 ± 6.9 min (Figueroa et al., 2011). Heart rate response, RER, and RPE were not different between the body weight conditions (Figueroa et al., 2011).

Gojanovic et al. (2012) had participants complete a graded exercise test on a land treadmill and on an AGT at 100, 95, 90, and 85% body weight. The authors found that VO_2 max values were similar for all conditions ranging from 66.6 ± 3.0 ml/kg/min to 65.0 ± 4.8 ml/kg/min for males and 63.0 ± 4.6 ml/kg/min to 60.7 ± 4.8 ml/kg/min for females (Gojanovic et al., 2012). Additionally, the time to reach VO_2 max was not significant for each condition, but there was a trend towards an inverse relationship between the amount of time to reach VO_2 max and body weight percentage (Gojanovic et al., 2012). The land treadmill time was 12.0 ± 2.5 min and the time during the 85% body weight condition was 14.1 ± 1.8 min (Gojanovic et al., 2012). Maximal HR in men was significantly different for the land treadmill at 190.4 ± 12.8 bpm compared to the 85% body weight condition on the AGT at 184.6 ± 9.1 bpm ($p < .05$; Gojanovic et al., 2012). For women, HR max was different between the land treadmill (190.4 ± 12.8 bpm) condition and both the 100% (189.4 ± 6.1 bpm) and 90% (189.3 ± 8.9 bpm) body weight conditions, but no differences were found between other conditions (Gojanovic et al., 2012). In another study, VO_2 max was measured on a land treadmill and on an AGT at 100% body weight (Raffalt et al., 2013). No differences were reported between the two conditions (Raffalt et al., 2013). There were also no differences in HR max, RER, and RPE. However, the time to reach VO_2 max was 34.5% ($p < .05$) longer on the AGT compared to the land treadmill (Raffalt et al., 2013).

Oxygen consumption has been measured during short bouts of exercise on the AGT at various speeds and levels of body weight percentage. Raffalt et al. (2013) recruited participants to exercise on an AGT at 2.78, 3.89, 5 m/s. The participants completed 3 trials lasting 12 min each. During the trials, the participants exercised at 100, 75, 50, and 25% body weight, with each condition lasting 3 min. Two high speed running bouts, each lasting for 20 s at 5.6 m/s and 6.1 m/s at each body weight condition, then followed. An 8-min rest period separated the lower and higher speed trials. As body weight percentage decreased, VO_2, HR, ventilation, and RPE decreased across all speeds ($p < .001$; Raffalt et al., 2013). McNeill, Kline, et al. (2015) had participants complete four, 4 min runs at 3.35, 3.84, 4.47, and 5.36 m/s on a land treadmill and on an AGT at 80 and 60% body weight. As body weight percentage decreased, VO_2 and HR decreased ($p < .001$) across all speeds (McNeill, Kline, et al., 2015). The decrease in VO_2 was 38% at the 60% body weight condition and the decrease was 34% at the 80% body weight condition (McNeill, Kline, et al., 2015). Oxygen consumption and HR also increased ($p < .001$) as velocity increased for all conditions (McNeill, Kline, et al., 2015). In another study by McNeill, de Heer, Williams, et al. (2015), changes in VO_2 were examined over the course of seven, 15-min trials when participants ran 5 min each at 90, 70, and 50% body weight at 70–80% VO_2 max. McNeill, de Heer, et al. (2015) found that VO_2 decreased as body weight percentage decreased ($p < .05$). For the first few trials at each body weight condition, VO_2 decreased ($p < .001$) from the previous trial (McNeill, de Heer, Williams, et al., 2015). Oxygen consumption stabilized after the second trial at

90% body weight, after the third trial at 70% body weight, and after the fourth trial at 50% body weight, indicating the participants became accustomed to running on the AGT with multiple trials (McNeill, de Heer, Williams, et al., 2015). In another study, participants exercised at 0.4, 1.3, 2.2, and 3.1 m/s for 5 min at each speed in a ramp protocol at 100, 67, and 33% body weight (Ruckstuhl, Schlabs, Rosales-Velderrain, & Hargens, 2010). Ruckstuhl et al. (2010) reported that VO_2, HR, and RPE decreased as body weight percentage decreased ($p < .001$). The percent decline in VO_2 for any body weight condition was greater at the faster speeds of 2.2 and 3.1 m/s ($p = .004$) compared to slower speeds of 0.4 and 1.3 m/s (Ruckstuhl et al., 2010).

Caloric Expenditure

Caloric expenditure decreases as body weight percentage decreases on an AGT. Though the decrease is not significant for either sex ($p = .67$ in males; $p = .08$ in females), males experienced a decreased caloric expenditure of approximately 27 kcals from 100–80% body weight, while females experienced a decrease of approximately 30 kcals for the same body weight conditions (Figueroa et al., 2011).

Speed

As body weight percentage decreases, running speed must increase in order to maintain intensity on an AGT. Gojanovic et al. (2012) reported significant differences in maximal speed in men while running on a land treadmill (5.47 ± 0.25 m/s) compared to an AGT (6.28 ± 0.44 m/s) at 85% body weight. In females, maximal running speed was higher at 95, 90, and 85% body weight compared to 100% body weight on an AGT and on a land treadmill (Gojanovic et al., 2012). Raffalt et al. (2013) reported significant differences in VO_2, HR, ventilation and breathing rate at 2.78, 3.89, and 5 m/s. As speed increased, VO_2, HR, ventilation, breathing rate, and RPE increased across all levels of body weight percentage (Raffalt et al., 2013). McNeill, Kline, et al. (2015) observed no difference in VO_2 at speeds of 3.35 (p = .724), 3.84 (p = .243), and 4.47 m/s (p = .204) when comparing 80 and 60% body weight. There was a significant difference ($p < .001$) in VO_2 at 5.36 m/s with 80% body weight (40.96 ml/kg/min) compared to 60% body weight (37.37 ml/kg/min; McNeill, Kline, et al., 2015). Oxygen consumption, HR, and RPE increased as speed increased ($p < .001$) across all levels of body weight percentage in the study by Ruckstuhl et al. (2010).

Ground Reaction Forces/Mechanics

As body weight percentage decreases, changes can be observed in ground reaction forces. Raffalt et al. (2013) measured ground reaction forces in participants running at 2.78, 3.89, 5 m/s at 100, 75, 50, and 25% body weight. Ground reaction forces decreased as body weight percentage decreased ($p < .001$), and forces increased as speed increased ($p < .001$; Raffalt et al., 2013). Additionally, Hoffman and Donaghe (2011) assessed ground reaction forces as participants walked at 0.49, 0.85, 1.25, and 1.56 m/s and ran at 1.79, 2.59, and 3.49 m/s while on an AGT at 100, 75 and 50% body weight. Peak ground reaction forces decreased as body weight support increased ($p < .001$; Hoffman & Donaghe, 2011). Vertical and horizontal ground reaction forces were examined by Grabowski and Kram (2008). Participants ran on an AGT at 3.0 and 4.0 m/s with 100, 75, 50, and 25% body weight, and at 5.0 m/s with 50 and 25% body weight. Vertical impact peak ground reaction forces, horizontal ground reaction forces and metabolic power ($p < .05$) increased as speed increased while decreasing as body weight decreased (Grabowski & Kram, 2008). Horizontal forces during running on a land treadmill can affect the metabolic cost of exercise (Chang & Kram, 1999). Participants ran on a land treadmill at 3.3 m/s while an assistive (positive) or impeding (negative) horizontal force was applied consisting of -6, -3, +3, +6, +9, +12, and +15% of the individuals body weight for 8 min each for each condition (Chang & Kram, 1999). Horizontal ground reaction forces were calculated from the horizontal braking and propulsive forces during running. During normal running conditions, these forces must be equal and opposite for a runner to maintain their position on a land treadmill (Chang & Kram, 1999). When assistive horizontal forces were applied, the breaking impulses increased while the propulsion impulse decreased; however, average vertical ground reaction forces did not change (Chang & Kram, 1999). Metabolic cost was significantly different when impeding and assistive horizontal forces were applied. The 6 and 15% body weight assistive forces decreased VO_2 22–33%, while the 6% body weight impeding force increased VO_2 30% ($p < .01$; Chang & Kram, 1999). Additionally, no differences in metabolic cost were observed between the five assistive horizontal forces (Chang & Kram, 1999).

CHAPTER III

METHODS

Participants

Healthy male and female participants (*n* = 12) were recruited and screened to include those who: (1) ran a minimum of 15 miles/week for the last 3 months prior to enrolling in the study; (2) were between the ages of 18 and 45 years old; (3) were without a musculoskeletal injury in the past 6 months; and (4) were without any cardiovascular, metabolic, or musculoskeletal disorders that would preclude them from exercising safely. Participants were asked to refrain from structured exercise 24 hr before the familiarization session and between each testing session. Participants were asked not to consume stimulants (e.g., caffeine) on the days of the familiarization and testing sessions. Participants were asked to drink an amount of water that is equivalent to their body weight in ounces the night before the familiarization and each testing session to ensure proper hydration (i.e., if weight was 70 kg, the participant drank 70 oz). The familiarization and testing sessions were completed at least 2 hr after meal consumption and at the same time each day. This study received approval from the Institutional Review Board at Texas Woman's University and Texas A&M University – Commerce.

Instruments

An Alter-G Anti-Gravity Treadmill (Alter-G M320, Fremont, CA) was used during the AGT exercise sessions. A Trackmaster Treadmill (TMX428CP, Full Vision, Newton, Kansas) was used during the land treadmill exercise session. A portable metabolic system (COSMED K5, Chicago, IL) was used to measure VO_2, EE, and RER during each exercise session. The metabolic system was calibrated before each test according to manufacturer's recommendations. Heart rate was measured using a Garmin heart rate monitor (Garmin International, Inc., Olathe, KS). Blood lactate was measured using a Lactate Scout analyzer (SensLab GmbH, Leipzig, Germany).

Procedures

Participants completed an informed consent and health history questionnaire to determine their eligibility to participate in the study. Participants who met the inclusion criteria were enrolled in the study. Anthropometric measurements, including height and weight, were assessed. Height was measured with a stadiometer and weight was measured with a digital scale. Resting HR was recorded at the end of a 5-min period where participants sat quietly while wearing the HR monitor. Resting HR was used to calculate 65–70 and 95–100% HRR as [((220 – age) – resting HR) x % intensity] + resting HR (Pescatello, 2014). These target HR values were used for all exercise sessions.

Study Design

A within-subjects design was used for this study. All participants completed 4 days of exercise testing with a minimum of 48 hr rest between sessions. Day 1 consisted of a submaximal treadmill test to estimate VO_2 max and a familiarization session on the AGT. Days 2 to 4 consisted of a 30 min exercise session on (1) land treadmill, (2) AGT at 90% body weight, and (3) AGT at 70% body weight. These three exercise sessions were completed in a random order and at approximately the same time of day for each participant.

Submaximal Exercise Test and Familiarization Sessions

To verify that participants ran on a regular basis, the fitness status of the participants was assessed using a submaximal exercise test on a land treadmill to estimate maximal oxygen consumption (VO_2 max). The submaximal test was a single-stage jogging test for fit adults (Vehrs, George, Fellingham, Plowman, & Dustman-Allen, 2007). Participants walked for 3 min followed by jogging for 3 min at a self-selected submaximal speed between 1.92 and 3.35 m/s at 0% grade (Vehrs et al., 2007). Steady state HR was determined during the second jogging stage when the HR change was less than 3 bpm over a 30 s period (Vehrs et al., 2007). Steady state HR, along with gender, age, body weight (kg), and jogging speed (mph) were used in the regression equation (R = .91, SEE = 2.52 ml/kg/min) described by Vehrs et al. (2007) to predict VO_2 max: 58.687 + (7.52 x gender; female = 0; male = 1) + (4.334 x mph) – (0.211 x kg) – (0.148 x HR) – (0.107 x age).

Following the submaximal test and a 15-min rest period, participants completed a familiarization session on the AGT to determine the speed needed to reach 65–70% HRR for 70 and 90% body weight conditions. Participants rested for 15 min between the two sessions on the AGT. After completion of the two familiarization sessions on the AGT, an additional 15-min rest period was allowed which was then followed by a run on the land treadmill to determine the speed needed to reach 65–70% HRR and 95–100% HRR.

To determine the speed needed to reach the desired HRR for each condition, participants ran on the treadmill for approximately 5–10 min at a speed estimated to achieve the desired HR based on the participant's running experience. During minutes 3–5, if the HR stayed within the desired range (65–70 or 95–100% HRR), the speed was recorded. If the HR did not remain within the desired range, a trial and error approach was used to adjust the treadmill speed until the participant maintained the desired HR for approximately 2 min. The speed needed to reach the desired HRR during each body weight and land treadmill condition was recorded and used during the appropriate testing session. At the conclusion of the familiarization session, participants were allowed to walk on the treadmill at 0.89 m/s for a recovery period. During the familiarization session and each testing session, participants were asked to allow their arms to swing in as comfortable a manner as possible, but not to hold on to the treadmill. On the AGT, the air chamber often prevents runners from using their typical arm swing motion.

For the AGT sessions, the treadmill and the participant's lower body was enclosed in an airtight pressure chamber. The participant wore specially designed neoprene shorts that zipped at the waist to attach to the pressure chamber. During the familiarization session, the participant was fitted for the appropriate size neoprene shorts. Participants stepped into the AGT and lifted the cockpit which supports the pressure chamber. The cockpit was locked into place with the tubing that comprises the cockpit slightly below the greater trochanter of the femur, as recommended by the manufacturer (*AlterG Anti-Gravity Treadmill M320/F320 Operation Manual*, 2015). The cockpit height was recorded and used for all exercise sessions on the AGT. The neoprene shorts were attached to the pressure chamber using the zipper. The participants stood in the AGT for calibration with their arms crossed across their chest. Once the AGT calibrated, the participant began exercise for the familiarization session.

30-min Exercise Trials

Participants returned to the lab for three additional exercise sessions consisting of running on a land treadmill, on an AGT at 90% body weight, and on an AGT at 70% body weight with at least 48 hr of rest between each testing session. The order of the exercise sessions was randomized and participants were blinded to the body weight percentage during the AGT sessions. Each testing session began with a 2 min self-paced warm-up at 0% grade, followed by running for 30 min at 65–70% HRR at 0% grade, and concluded with running to volitional fatigue at 0% grade. The speed for the run to volitional fatigue was consistent for all testing sessions and utilized the speed needed to reach 95–100% HRR on the land treadmill as determined during the familiarization session. A fan was positioned near the treadmill to provide air circulation during all testing sessions. For the AGT sessions, the treadmill and the participant's lower body were enclosed in an airtight pressure chamber as previously described. During each exercise session, VO_2, EE, TTE, HR, RER, blood lactate, and RPE were measured. Oxygen consumption, RER, and HR were recorded at 5, 15, and 30 min of exercise. Rating of perceived exertion was recorded at 15 and 30 min of exercise. When participants reached volitional fatigue, the TTE was recorded, along with VO_2, EE, RER, HR, and RPE. Blood lactate concentration was measured immediately following the run to volitional fatigue while the participants began a cool down period of walking at 0.89 m/s and 0% grade on the treadmill. The concentration was used to confirm participants gave maximal effort during the run to volitional fatigue and was measured by collecting a blood sample from the fingertip while walking. Participants were monitored to ensure HR returned to near normal levels before they were allowed to leave. Participants were reminded of their next scheduled testing session and to avoid structured physical activity between sessions.

Data Analysis

A one-way repeated measures analysis of variance was used for statistical analysis to determine differences in EE, TTE, VO_2, HR, RER, blood lactate, and RPE during each of the three exercise conditions. Level of significance was set a priori at $p < .05$, and all data are reported as mean ± SD. Descriptive statistics are reported for the participant's demographic information, including height, weight, age, and estimated VO_2 max.

CHAPTER IV

PRESENTATION OF FINDINGS

The purpose of this study was to determine cardiorespiratory differences between running on a land treadmill and on an AGT during 30 min of exercise followed by a run to volitional fatigue. Twenty-three individuals volunteered to participate in the study. Of those, five did not meet inclusion criteria as a trained runner, one was recovering from an injury, and five did not schedule the required sessions. A total of 12 participants (5 males and 7 females) completed the familiarization and all testing sessions for the study. Participant demographics are in Table 1. Participants met the criteria of running 15 miles/week, but had varying levels of training as a runner (mileage 32 ± 19.9 miles/week).

Table 1

Participant Demographics

Age (years)	22.0	±	4.3
Height (cm)	171.3	±	6.9
Weight (kg)	68.0	±	13.0
BMI (kg/m^2)	23.1	±	3.6
VO_2 max (ml/kg/min)	50.7	±	7.8

Note. VO_2 max estimated from a submaximal treadmill test.

Time to reach volitional fatigue is reported in Figure 1. Both the 70% AGT (p =.014) and 90% AGT (p = .007) conditions were significantly greater than the land treadmill condition.

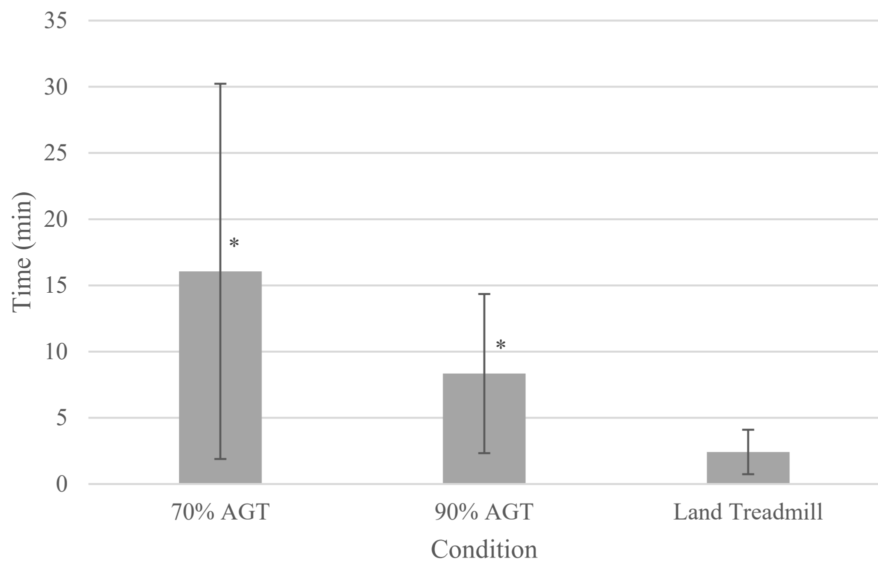

Figure 1. Time to volitional fatigue for each condition. *Significantly greater than land treadmill condition, $p < .05$, $\eta^2 = .501$; AGT: anti-gravity treadmill

Blood lactate at volitional fatigue was not different between conditions (70% AGT: 13.2 ± 9.2 mmol/L; 90% AGT: 13.4 ± 7.3 mmol/L; land treadmill: 14.4 ± 6.9 mmol/L; p = .883, η^2 = .011). Rating of perceived exertion at 30 min of exercise (70% AGT: 10.8 ± 3.3; 90% AGT: 11.0 ± 2.4; land treadmill: 11.1 ± 2.8; p = .721, η^2 = .029) and at volitional fatigue (70% AGT: 17.7 ± 2.6; 90% AGT: 18.3 ± 1.6; land treadmill: 18.5 ± 1.6; p = .359, η^2 = .081) was not different between conditions. Variables for 30 min of exercise for each condition are reported in Table 2. Oxygen consumption for 70% AGT (p = .004) and 90% AGT (p = .012, η^2 = .546) were significantly less than the land treadmill condition. At 30 min of exercise, HR for 70% AGT was significantly less than the land treadmill condition (p = .001, η^2 = .582). Target HR during the steady state run was 65–70% HRR (150 ± 3 to 157 ± 3 bpm). Energy expenditure for 70% AGT (p = 0.003) and 90% AGT (p = .013, η^2 = .563) was significantly less than the land treadmill condition.

Table 2

30-Min Exercise Values for Each Condition

	70% AGT	90% AGT	Land Treadmill
VO_2 (ml/kg/min)	28.2 ± 6.7*	31.1 ± 6.9*	35.4 ± 8.6
VCO_2 (ml/kg/min)	23.6 ± 4.9	25.3 ± 5.2	28.8 ± 7.5
HR (bpm)	153 ± 11*†	163 ± 9	168 ± 8
RER	0.86 ± 0.07	0.84 ± 0.05	0.85 ± 0.06
EE (kcal)	259.5 ± 63.7*	284.5 ± 70.0*	318.9 ± 86.1

Note. *significantly less than land treadmill condition, $p < .05$; †Significantly less than 90% AGT condition, p = .013. AGT: anti-gravity treadmill; VO_2: oxygen consumption; VCO_2: carbon dioxide production; HR: heart rate; RER: respiratory exchange ratio; EE: total accumulated energy expenditure.

Variables for volitional fatigue for each condition are reported in Table 3. VO_2 for 70% AGT was significantly less the land treadmill condition (p = .005, η^2 = .477). The RER for 70% AGT (p = .002) and 90% AGT (p = .007, η^2 = .543) was significantly less than the land treadmill condition. Average VO_2 and HR responses during exercise and the run to volitional fatigue are in Figures 2 and 3. During the 30-min run, 3–7 participants reached the target 65–70% HRR at 15 min of exercise (70% AGT: n = 3; 90% AGT: n =

7; land treadmill: $n = 4$) and 1–3 participants at 30 min of exercise (70% AGT: $n = 1$; 90% AGT: $n = 3$; land treadmill: $n = 1$).

Table 3

Volitional Fatigue Values for Each Condition

	70% AGT	90% AGT	Land Treadmill
VO_2 (ml/kg/min)	37.1 ± 10.0*	41.6 ± 10.4	46.9 ± 9.8
VCO_2 (ml/kg/min)	32.4 ± 8.8	37.0 ± 9.7	46.7 ± 10.3
HR (bpm)	180 ± 15†	186 ± 10	188 ± 9
RER	0.9 ± 0.06*	0.91 ± 0.07*	1.02 ± 0.09
EE (kcal)	396.5 ± 136.6	383.6 ± 100.1	351.5 ± 84.6

Note. *significantly less than land treadmill condition, $p < .05$; †Significantly less than 90% AGT condition, $p = .046$. AGT: anti-gravity treadmill; VO_2: oxygen consumption; VCO_2: carbon dioxide production; HR: heart rate; RER: respiratory exchange ratio; EE: total accumulated energy expenditure.

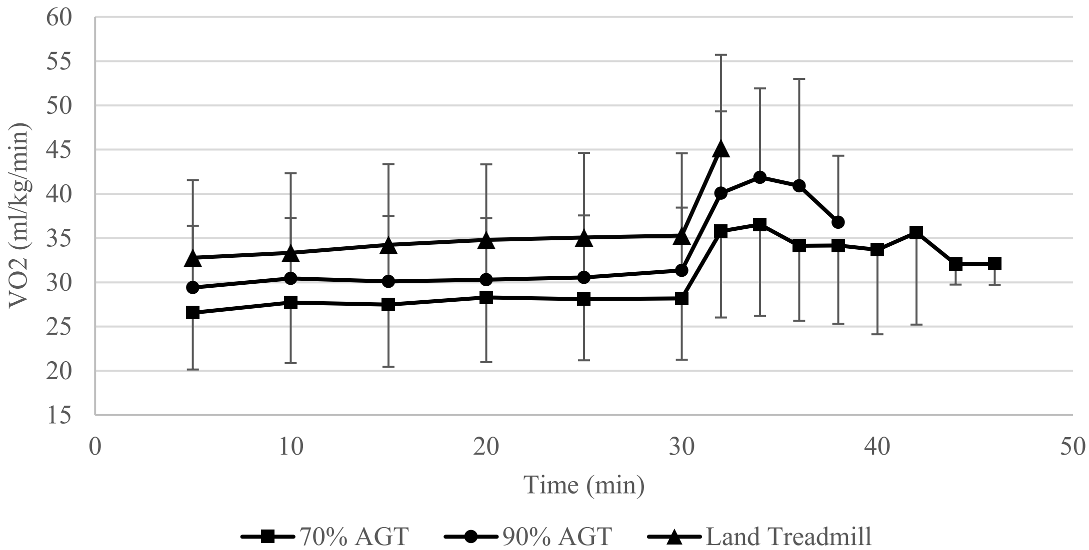

Figure 2. VO_2 responses during exercise and run to volitional fatigue. Run to volitional fatigue began at 30 min. AGT: anti-gravity treadmill; VO_2: oxygen consumption.

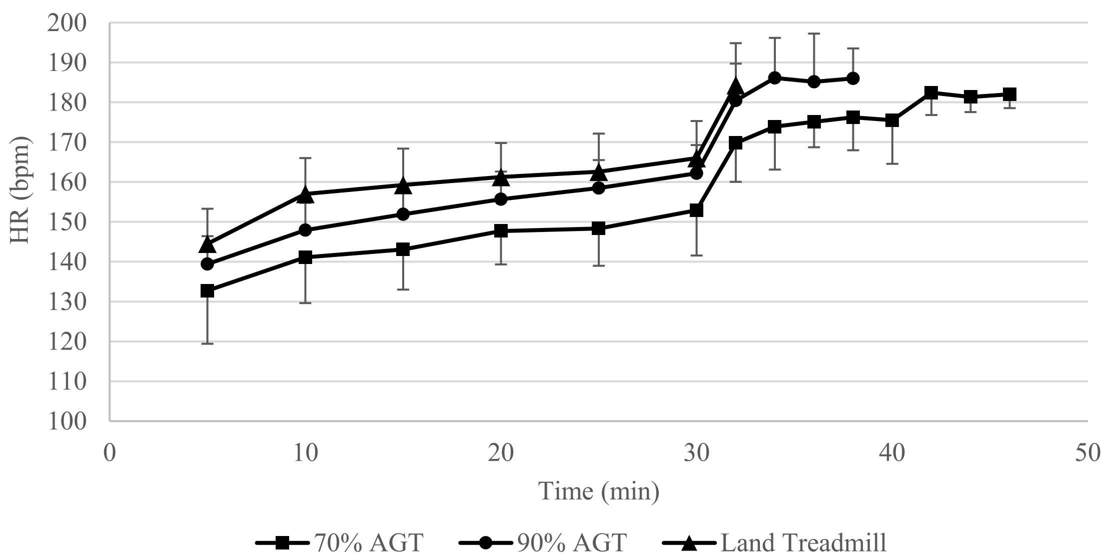

Figure 3. HR responses during exercise and run to volitional fatigue. Target HR set at 65–70% HRR for 30-min run. Participants at target HR at 30 min of exercise: 70% AGT (n = 1); 90% AGT (n = 3); land treadmill (n = 1). Run to volitional fatigue began at 30 min. AGT: anti-gravity treadmill; HR: heart rate.

CHAPTER V

DISCUSSION AND SUMMARY

The purpose of this study was to determine cardiorespiratory differences between running on a land treadmill and on an AGT during 30 min of exercise followed by a run to volitional fatigue. There were two research hypotheses for this study: (1) AGT conditions would have increased values for TTE compared to the land treadmill, and (2) AGT conditions would have a decreased EE, VO_2, HR, RER, blood lactate, and RPE compared to the land treadmill. Findings from this study support the first hypothesis, as the time to reach volitional fatigue was seven times greater for the 70% and three times greater for the 90% AGT conditions compared to the land treadmill condition. The second hypothesis was partially supported by the findings of this study. At 30 min of exercise, total EE was 11–19% lower in the two AGT conditions compared to the land treadmill conditions; however, at the end of the run to volitional fatigue, there were no differences between conditions. Similarly, average VO_2 was 12–20% lower for the two AGT conditions compared to the land treadmill condition at 30 min of exercise. At volitional fatigue, average VO_2 during the 70% AGT condition was 21% lower than the land treadmill condition, but no differences were observed between the 90% AGT and the land treadmill condition. Heart rate at 30 min of exercise for the 70% AGT condition was lower than the 90% AGT and the land treadmill conditions, while HR at volitional fatigue for the 70% AGT condition was lower compared to the 90% AGT condition. There were no differences in RER at 30 min of exercise, but at volitional fatigue, RER was approximately 11% lower for the two AGT conditions compared to the land treadmill condition. No differences were observed between conditions for RPE at 30 min of exercise or at volitional fatigue. Additionally, no differences were observed for blood lactate at volitional fatigue. These findings may be helpful for athletes who need to maintain or improve their cardiovascular endurance when they have an injury that prevents them from exercising in a full weight bearing capacity. The AGT is one option for athletes who require partial weight bearing when completing cardiovascular endurance training. Running on the AGT at reduced body weight may not allow the athlete to achieve as high of a VO_2 or HR response during exercise at a steady state. Athletes may need to exercise for a much longer duration when partial weight bearing in order to reach similar levels of cardiovascular stress.

This appears to be the first study to evaluate the time needed to reach volitional fatigue following a steady state run with partial weight bearing on an AGT compared to a land treadmill. Non-significant trends towards an inverse relationship between body weight and time to reach VO_2 max were observed in previous studies (Figueroa et al., 2011; Gojanovic et al., 2012). Raffalt et al. (2013) reported a 34.5% increase in time to reach VO_2 max on an AGT at 100% body weight compared to a land treadmill. Raffalt et al. (2013) suggested the pressure chamber for the AGT condition provided support to the participants, allowing them to continue running even though they were experiencing fatigue. The current study did not include a VO_2 max test for any of the conditions, but time to reach volitional fatigue was greater with the 70% AGT and 90% AGT conditions compared to the land treadmill condition. As suggested by Raffalt et al. (2013), the increased run time for the AGT conditions could be partially due to the support from the pressure chamber, allowing the participants to continue running as fatigue increased. The design of the pressure chamber requires the participants to wear shorts that are attached to the chamber by a zipper. The chamber provides horizontal support that assists the runner in maintaining their position on the treadmill (Grabowski & Kram, 2008; Raffalt et al., 2013). Assistive horizontal forces can reduce the propulsive forces required to allow the runner to maintain their position on the treadmill while reducing the metabolic cost of running (Chang & Kram, 1999). As the runner begins to experience fatigue, the assistive horizontal forces from the pressure chamber of the AGT reduces the demand of the runner to generate these forces, allowing them to continue running (Chang & Kram, 1999; Grabowski & Kram, 2008; Raffalt et al., 2013). Additionally, the pressure chamber provides vertical support to the runner as part of the unweighting process. As body weight support increases, ground reaction forces (Cutuk et al., 2006; Grabowski & Kram, 2008; Hoffman & Donaghe, 2011; Raffalt et al., 2013; Sainton et al., 2015), contact time, and step frequency decrease, while stride length and flight time increase (Barnes & Janecke, 2017; Cutuk et al., 2006; Raffalt et al., 2013; Sainton et al., 2015). The horizontal support from the pressure chamber and the reduced forces when running lower the metabolic demand, allowing the participant to run longer before reaching fatigue.

In the current study, the EE at 30 min of exercise in the 70% AGT and 90% AGT conditions was decreased compared to the land treadmill condition. This is similar to the results of Figueroa et al. (2011), who reported EE decreased as weight bearing status decreased. In the current study, EE at volitional fatigue was not different between the conditions. However, the time to reach volitional fatigue was significantly greater in the 70% AGT and 90% AGT conditions compared to the land treadmill condition, which would account for the similarities of EE between conditions at fatigue. In previous reports, VO_2 and HR were lower as percent weight bearing decreased when running for 3 to 5 min on an AGT at set speeds (Barnes & Janecke, 2017; McNeill, de Heer, Williams, et al., 2015; McNeill, Kline, et al., 2015; Raffalt et al., 2013; Ruckstuhl et al., 2010). In the current study, participants ran for a longer time during the 30-min run at steady state. These results were similar in that VO_2 was lower when running during the two AGT conditions compared to the land treadmill. Average HR in this study was similar to the value reported in these other studies in that it was lower during the 70% AGT condition compared to the other two conditions, but average HR was not different during the 90% AGT condition compared to the land treadmill condition. Differences in HR at 30 min of exercise can partially be explained by the methodology used for the study. The intent was for participants to run at 65–70% HRR at a set speed for the 30 min; however, the speed determined during familiarization did not produced the desired 65–70% HRR during the exercise sessions for some participants. During the 30-min run, 3–7 participants reached the target 65–70% HRR at 15 min of exercise (70% AGT: n = 3; 90% AGT: n = 7; land treadmill: *n* = 4) and 1–3 participants at 30 min of exercise (70% AGT: *n* = 1; 90% AGT: *n* = 3; land treadmill: *n* = 1).

Reduced metabolic demand with partial weight bearing exercise may be due to altered gait mechanics or horizontal support from the pressure chamber, as previously mentioned, or it could be due to reduced muscle activation. Hunter, Seeley, Hopkins, Carr, and Franson (2014) assessed muscle activation patterns via electromyography (EMG) for various muscles in the lower extremity at 100, 80, 60, and 40% body weight. Muscles providing support to the body, such as the vastus lateralis, vastus medialis, rectus femoris, gastrocnemius, gluteus maximus, and gluteus medius, exhibited reduced muscle activation as weight bearing decreased (Hunter et al., 2014). However, muscle activation of the hip adductors during the swing phase, and the activation of the hamstrings during the stance phase, were not affected by weight bearing status (Hunter et al., 2014). In other studies, overall muscle activation decreased as weight bearing decreased (Liebenberg et al., 2011; Mercer, Applequist, & Masumoto, 2013; Sainton et al., 2015), and increased as speed increased (Liebenberg et al., 2011; Mercer et al., 2013). When body weight support was 50% or less, increasing speed did not cause muscle activation to increase back to its normal level at full weight bearing (Mercer et al., 2013). This decrease in muscle activation when running with partial weight bearing may reduce metabolic demand, which may help explain the observed VO_2 and HR responses in the current study.

When running with partial weight bearing, there are mixed results when reporting RPE. McNeill, Kline, et al. (2015) and Ruckstuhl et al. (2009) observed a decrease in RPE as body weight support increased; however, Sainton et al. (2015) and Raffalt et al. (2013) did not observe changes in RPE as body weight support increased. Additionally, Hoffman and Donaghe (2011) did not observe changes in RPE as body weight support increased when participants ran at a speed needed to reach an average VO_2 of 25 ml/kg/min. The results of the current study are similar to Hoffman and Donaghe (2011), in that participants ran at a speed needed to reach 65–70% HRR for 30 min and 95–100% HRR until volitional fatigue, rather than running at a set speed for all participants. In the current study, no changes were observed for RPE at 30 min of exercise or at volitional fatigue between any of the conditions. Similarly, there are mixed results for RER, as McNeill, Kline, et al. (2015) observed a decrease in RER as weight bearing decreased, but Raffalt et al. (2013) observed no differences in RER between a land treadmill and AGT. In the current study, at the end of the 30-min steady state run, there were no differences in RER between conditions; however, at volitional fatigue, RER in both AGT conditions was lower than the land treadmill condition. Blood lactate at volitional fatigue was not different between conditions in the current study. This is in agreement with Raffalt et al. (2013), who did not observe changes in blood lactate. However, Gojanovic et al. (2012) reported decreased lactate levels in men at 85% body weight support compared to a land treadmill. Blood lactate concentration was used to confirm participants gave maximal effort during the run to volitional fatigue as indicated by a concentration greater than 8.0 mmol/L. Blood lactate was measured immediately after exercise and average concentration was 13.2–14.4 mmol/L, suggesting maximal effort was given by participants. The differences in study design related to running speed, incline, weight bearing support, and duration make it difficult to compare results, but may explain why there are mixed findings for many of the variables. Though there are some general similarities in HR and VO_2 responses while running with partial body weight support, Sainton et al. (2015) noted the complex nature of gait mechanics and muscle activation may affect the responses to running with partial body weight support. As suggested by Farina, Wright, Ford, Wirfel, and Smoliga (2017), differences in observed cardiovascular and mechanical responses may be a result of the variation in study design.

Strengths and Limitations

This study appears to be the first to examine cardiovascular responses on an AGT for a duration of 30 min with a run to volitional fatigue. Other strengths of this study include the use of a within-subjects design, which limited between-subject variability. Each exercise trial was also conducted at approximately the same time of day. Participants were also instructed to avoid exercise 24 hr before each trial and avoid any stimulants the day of the trial.

Limitations related to the internal validity of the study include the speed of the AGT treadmill and lack of control of menstrual phase. The AGT model used in this study had a maximum speed of 5.4 m/s. Some of the participants could run faster than this speed, which may have prolonged the time needed to reach volitional fatigue, especially in the 70% AGT condition. Menstrual cycle information was not obtained from female participants, which may have affected results for females. However, the pattern of responses for males and females across the three conditions were very similar for all the outcome variables. So it does not appear menstrual cycle had much influence on the results of the present study. Additionally, there was a limitation due to the methodology used to determine the speed needed to reach 65–70% HRR for participants. During familiarization, participants achieved 65–70% HRR at a set speed, but during exercise sessions, not all participants maintained the desired HRR during the 30-min run as planned.

There were also limitations related to the external validity of the current study. One limitation was that participants were healthy, trained runners, and the results may not be applicable to individuals who are sedentary, unfit, recreationally active, or injured. Also, as already noted, the maximum speed of the AGT treadmill was 5.4 m/s. Individuals choosing to utilize the AGT as a training tool when full weight bearing is not possible should consider the maximum speed of the AGT. Only the 70% and 90% AGT conditions were evaluated in the current study due to the accuracy of body weight support from the AGT (McNeill, de Heer, Bounds, et al., 2015), and results may be different at other levels of body weight support. Additionally, differences between gender and ethnicity were not evaluated in this study, and thus results cannot be applied separately to those populations. In the current study, participants ran at 65–70% HRR and 95–100% HRR, which requires resting HR to be determined. Participants sat quietly for 5 min to assess resting HR, and HRR was calculated. If the participant's HR did not truly reach a resting level, this could have affected the results of the study. Lastly, a submaximal treadmill test was used to estimate VO_2 max, and results cannot be applied to prescribe exercise intensity based on a percentage of VO_2 max.

Conclusion

Heart rate, VO_2, and total EE were decreased as weight bearing decreased when running at a steady state for 30 min on the AGT compared to the land treadmill. Reducing body weight while running on an AGT may decrease metabolic demand, but increasing running intensity may be able to reduce the effects of body weight support at some levels of unweighting. These results suggest that individuals choosing to exercise in a partial weight bearing environment on an AGT may need to adjust exercise intensity to reach the desired cardiometabolic response.

Future Studies

The long-term effects of using an AGT as a training tool in fit and unfit individuals should be examined in future studies. Training should be utilized to determine if the AGT can be used to maintain or improve cardiovascular fitness in fit, unfit, healthy, and injured individuals. In the current study, participants were required to run a minimum number of miles weekly, but a maximum was not specified. An upper limit to the weekly mileage for participants, or evaluating responses to exercise with body weight support for individuals with different levels of running experience should be considered. An attempt to determine total work performed during exercise with body weight support on an AGT should also be considered. Finally, outcomes for return to play rehabilitation protocols for injured athletes when utilizing an AGT compared to a land treadmill or other method of body weight support during exercise should be evaluated.

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APPENDIX A

Institutional Review Board Approval

Institutional Review Board
Office of Research and Sponsored Programs
P.O. Box 425619, Denton, TX 76204-5619
940-898-3378
email: IRB@twu.edu
http://www.twu.edu/irb.html

TWU
EXAS WOMAN'S UNIVERSITY
DENTON DALLAS HOUSTON

DATE: March 24, 2017

TO: Ms. Sarah Mitchell
Kinesiology

FROM: Institutional Review Board (IRB) - Denton

Re: Approval for Physiological Responses to Running on a Land and Anti-gravity Treadmill (Protocol #: 19481)

The above referenced study was reviewed at a fully convened meeting of the Denton IRB (operating under FWA00000178). The study was approved on 3/24/2017. This approval is valid for one year and expires on 3/24/2018. The IRB will send an email notification 45 days prior to the expiration date with instructions to extend or close the study. It is your responsibility to request an extension for the study if it is not yet complete, to close the protocol file when the study is complete, and to make certain that the study is not conducted beyond the expiration date.

If applicable, agency approval letters must be submitted to the IRB upon receipt prior to any data collection at that agency. A copy of the approved consent form with the IRB approval stamp is enclosed. Please use the consent form with the most recent approval date stamp when obtaining consent from your participants. A copy of the signed consent forms must be submitted with the request to close the study file at the completion of the study.

Any modifications to this study must be submitted for review to the IRB using the Modification Request Form. Additionally, the IRB must be notified immediately of any adverse events or unanticipated problems. All forms are located on the IRB website. If you have any questions, please contact the TWU IRB.

cc. Dr. David Nichols, Kinesiology
Graduate School

TWU
TEXAS WOMAN'S UNIVERSITY
DENTON DALLAS HOUSTON

Institutional Review Board
Office of Research and Sponsored Programs
P.O. Box 425619, Denton, TX 76204-5619
940-898-3378
email: IRB@twu.edu
http://www.twu.edu/irb.html

DATE: March 12, 2018

TO: Ms. Sarah Mitchell
Kinesiology

FROM: Institutional Review Board (IRB) - Denton

Re: Extension for Physiological Responses to Running on a Land and Anti-gravity Treadmill (Protocol #: 19481)

The request for an extension of your IRB approval for the above referenced study has been reviewed by the TWU IRB (operating under FWA00000178) and appears to meet our requirements for the protection of individuals' rights.

If applicable, agency approval letters must be submitted to the IRB upon receipt prior to any data collection at that agency. If subject recruitment is on-going, a copy of the approved consent form with the IRB approval stamp is enclosed. Please use the consent form with the most recent approval date stamp when obtaining consent from your participants. A copy of the signed consent forms must be submitted with the request to close the study file at the completion of the study.

This extension is valid one year from March 24, 2018. Any modifications to this study must be submitted for review to the IRB using the Modification Request Form. Additionally, the IRB must be notified immediately of any unanticipated incidents. All forms are located on the IRB website. If you have any questions, please contact the TWU IRB.

cc. Dr. David Nichols, Kinesiology
Graduate School

APPENDIX B

Informed Consent Form

TEXAS WOMAN'S UNIVERSITY
CONSENT TO PARTICIPATE IN RESEARCH

Title: Physiological Responses to Running on a Land and Anti-gravity Treadmill

Principle Investigator: Sarah Mitchell.. smitchell14@twu.edu 903-886-5543
Advisor: David Nichols, Ph.D. .... DNichols@twu.edu 940-898-2575
Advisor: Brandon Rhett Rigby, Ph.D. .... BRigby@twu.edu 940-898-2473
Research Assistant: Tori Hummer .... thummer@leomail.tamuc.edu 817-694-0641

Purpose of the Research
You are being asked to participate in a research study for Sarah Mitchell's dissertation. The purpose of this research study is to determine differences between running on a land treadmill and on an anti-gravity treadmill during 30 minutes of exercise followed by a run to volitional fatigue. Specifically, this study will determine differences in caloric expenditure, oxygen consumption, time to exhaustion, peak heart rate, respiratory exchange ratio, blood lactate, and rating of perceived exertion. The anti-gravity treadmill is a treadmill system that reduces weight bearing status during exercise by utilizing an airtight pressure chamber that surrounds the treadmill and your lower body. The Alter-G treadmill will be used for the anti-gravity running sessions for this study.

Location and Time Commitment
This research study will take place at Hulsey Therapy Services Rehab & Sports Medicine Clinic in Commerce, TX. You will be asked to complete a familiarization session and 3 testing sessions. The familiarization session will take a minimum of 110 minutes but may take longer due to determining the running speed needed to reach the desired heart rate. The maximum amount of time for this session is estimated to be 2.5 hours. Each of the 3 testing sessions will require approximately 40 minutes of exercise, including a warm up and recovery period. The duration of exercise will be dependent on how long it takes you to reach volitional fatigue. The maximum amount of time for the testing session is estimated to be 1 hour. Your total time commitment is expected to be approximately 5.5 hours.

Description of Procedures
You are being asked to participate in this study if you meet the following requirements: (1) you have run a minimum of 15 miles/week for the last 3 months prior to enrolling in the study to ensure your ability to complete the exercise protocol; (2) you are between the ages of 18 and 45 years old; (3) you are without musculoskeletal injury in the past 6 months to reduce the effect that injury may have on the results; and (4) you are without any cardiovascular, metabolic, or musculoskeletal disorders that would preclude them from exercise. If you meet these criteria and want to enroll in the research study, you will be asked to complete a health history and physical activity readiness questionnaire.

You will be asked to come to the clinic for four visits (1 familiarization session and 3 testing sessions) with a minimum of 48 hours between each visit. You will be asked to refrain from structured exercise 24 hours before the familiarization session and between each testing session. You will also be asked not to consume stimulants (e.g., caffeine) on the days of the familiarization and testing sessions. You will be asked to drink an amount of water that is equivalent to your body weight in ounces the night before the familiarization and each testing session to ensure proper hydration (i.e. if your weight is 70 kilograms, drink 70 ounces; weight in pounds ÷ 2.2 = kilograms). The familiarization and testing sessions will be completed at least 2 hours after meal consumption and at the same time each day.

During the familiarization session you will complete measurements of height, weight, and age. You will be fitted with a polar heart rate monitor to measure resting heart rate, which will be recorded at the end of a 5 minutes period where you sit quietly. Resting heart rate will be used to calculate 65-70 and 95-100% heart rate reserve as [((220 – age) – resting heart rate) x % intensity] + resting heart rate. These target heart rate values will be used for all exercise sessions.

Next, you will complete a submaximal test on a land treadmill to estimate maximal oxygen consumption. The submaximal test will be a single-stage jogging test for fit adults. You will walk for 3 minutes followed by jogging for 3 minutes at a self-selected submaximal speed between 4.3 and 7.5 mph at 0% grade. Steady state heart rate will be determined during the second jogging stage when your heart rate change is less than 3 bpm over a 30 s period. Steady state heart rate, along with gender, age, body weight (kg), and jogging speed (mph) will be used in the regression equation to predict maximal oxygen consumption. You will be allowed a 15 minute rest period after the submaximal test. You will be asked to wear fitted neoprene shorts that will zip into the airtight pressure chamber on the Alter-G treadmill. You will complete a familiarization session on the anti-gravity treadmill to determine the speed needed to reach 65-70% heart rate reserve for two different body weight percentages. You will rest for 15 minutes between the two body weight conditions, followed by a run on the land treadmill to determine the speed needed to reach 65-70% heart rate reserve and 95-100% heart rate reserve. You will be allowed to remove the fitted neoprene shorts for the land treadmill running. To determine the speed needed to reach the desired heart rate reserve for each condition, you will run on the treadmill for approximately 5 minutes at a speed estimated to achieve the desired heart rate based on your running experience. During minutes 3-5, if your heart rate stays within the desired range (65-70 or 95-100% heart rate reserve) the speed will be recorded. If your heart rate does not remain within the desired range, there will be trial and error in adjusting the treadmill speed until you are able to maintain the desired heart rate for approximately 2 minutes. The speed needed to reach the desired heart rate reserve during each body weight condition will be recorded and used during the appropriate testing session.

During the familiarization session and each testing session, you will be asked to allow your arms to swing in a comfortable manner, but not to hold on to the treadmill. For the anti-gravity treadmill sessions, once you have been fitted for the appropriate size neoprene shorts, you will step into the anti-gravity treadmill and lift the carriage system which supports the air pressure chamber. The carriage will be locked into place at the appropriate height at your hips. The carriage height will be recorded and used for all exercise sessions on the anti-gravity treadmill. The neoprene shorts will be attached to the pressure chamber using the zipper. You will stand in the anti-gravity treadmill for calibration with your arms crossed across your chest. Once the anti-gravity treadmill is calibrated, you will begin exercise.

Summary of the familiarization session: (1) height, weight, age, and gender are recorded; (2) polar heart rate monitor positioned around your chest; (3) sit for 5 minutes to measure resting heart rate; (4) submaximal treadmill test; (5) 15 minute rest; (6) running on anti-gravity treadmill at first body weight percentage at a speed to reach 65-70% heart rate reserve; (7) 15 minute rest; (8) running on anti-gravity treadmill at second body weight percentage at a speed to reach 65-70% heart rate reserve; (9) 15 minute rest; (10) running on a land treadmill at a speed to reach 65-70% heart rate reserve; (11) running on a land treadmill at a speed to reach 95-100% heart rate reserve; and (12) walking on a land treadmill at 2 mph for a recovery period.

You will be asked to return to the lab for three additional exercise sessions consisting of running on a land treadmill and on an anti-gravity treadmill at two different body weight percentages with at least 48 hours of rest between each testing session. You will complete the exercise sessions in a random order. For each testing session, you will have a polar heart rate monitor positioned on your chest. You will be fitted with a mouthpiece that will be connected to the portable metabolic system to measure oxygen consumption and caloric expenditure. During each testing session, you will begin with a 2 minute self-paced warm-up at 0% grade, followed by running for 30 minutes at 65-70% heart rate reserve at 0% grade, and will conclude with running to volitional fatigue at 0% grade. The speed for the run to volitional fatigue will be consistent for all testing sessions and will utilize the speed needed to reach 95-100% heart rate reserve on the land treadmill as determined during the familiarization session. You will be given 4 ounces of water to drink at 15 minutes of exercise. A fan will be positioned near the treadmill to provide air circulation during all testing sessions. For the anti-gravity treadmill sessions, the treadmill and your lower body will be enclosed in an airtight pressure chamber as previously described. During each exercise session, oxygen consumption, caloric expenditure, time to exhaustion, peak heart rate, respiratory exchange ratio, blood lactate, and rating of perceived exertion will be measured. When you reach volitional fatigue, the time to exhaustion will be recorded, along with oxygen consumption, caloric expenditure, respiratory exchange ratio, heart rate, and rating of perceived exertion. Volitional fatigue is defined as running until fatigue or exhaustion prevents you from maintaining pace with the treadmill or you place your hands on the treadmill to maintain balance. Blood lactate concentration will be measured immediately following the run to volitional fatigue while you begin a cool down period of walking at 2 mph and 0% grade on the treadmill. Blood lactate concentration will be measured by collecting a blood sample from your fingertip while you are walking. The blood will be analyzed and disposed of immediately. You will be monitored to ensure your heart rate returns to near normal levels before you are able to leave.

Potential Risks

Loss of Confidentiality: There is a potential risk of loss of confidentiality in all email, downloading, electronic meetings and internet transactions. Communication between the PI and participants may occur through email or internet connections. To minimize this risk, data collected for the study will be stored on a password-protected computer. All data collection sheets will be locked in the PIs office. You will be assigned an ID number which will be used on all data collection sheets. Your name and assigned ID number will be stored on a master list that will be locked in the PIs office and #2 stored separately from all other data. Confidentiality will be protected to the extent that is allowed by law.

Cardiac Event: There is a risk that you may sustain a heart attack, cardiac arrest, or a cardiac event during exercise. To minimize this risk, you must be age 45 or younger and will complete the PAR-Q to determine if you can safely participate in exercise. The PI is trained in CPR and AED techniques and will be present at all exercise sessions. An AED and phone are accessible in the facility in case of emergency.

Shortness of breath, lightheadedness, and/or nausea: There is a risk that you may sustain shortness of breath, lightheadedness, and/or nausea during exercise. To minimize this risk, you will complete a warm-up before exercise testing and a recovery period after exercise. Your heart rate will be monitored before, during, and after exercise.

Muscle soreness/fatigue or joint soreness: There is a risk that you may experience muscle soreness or fatigue, as well as joint soreness after the exercise sessions. To minimize this risk, you will complete a warm-up before exercise and a recovery period after exercise. You will be asked frequently how you feel and if you are okay to continue with the study. In the unlikely event that you experience pain, discomfort, or injury during or after a session, you will be encouraged to seek medical care at a local health care provider.

Possibility of Embarrassment: There is a risk that you may become embarrassed during participation due to wearing the tight fitted neoprene shorts during the exercise sessions on the anti-gravity treadmill. You will wear your own shorts under the neoprene shorts. To minimize risk of embarrassment, you may request a screen be placed around the treadmill while you are exercising.

Compromise of Hygiene: The neoprene shorts that you will wear during anti-gravity treadmill exercise sessions will be previously worn by other participants. To minimize the risk of compromised hygiene, the neoprene shorts will be cleaned after each use. Additionally, you will wear your own shorts under the neoprene shorts.

Allergy to Neoprene: There is a risk that you may be allergic to neoprene or have skin reactions to the neoprene. To minimize the risk of skin reaction, you are encouraged to wear shorts that will minimize skin contact with the neoprene shorts. In the unlikely event that you experience an allergic reaction to the neoprene, you will be encouraged to seek medical care at a local health care provider.

Loss of time: You will be asked to complete 4 sessions with a total time commitment of approximately 5.5 hours. To minimize the risk of unwanted loss of time, exercise sessions will be scheduled with your input. You will be informed of your scheduled sessions and reminders will be sent via email or phone based on your preference. You will be informed of the expected time to complete each session.

#3 Infection: There is a risk of infection at the site of the finger prick. To minimize the risk of infection, PI will wear gloves when performing the finger prick and collecting the blood sample for lactate analysis. The participant's finger will be cleaned with an alcohol swab before pricking the finger. After the blood is collected from the fingertip, gauze and a bandaid will be applied to stop the bleeding. The participant will be informed of the signs of infection to watch for and encouraged to seek medical attention in the event they develop any signs of infection.

#3 Injury/Falling: There is a risk of injury/falling while completing exercise. Every precaution will be taken by the researchers to prevent any injury or problem that could happen during the research study. If an injury should occur all proper and necessary medical and/or first aid procedures will be followed as dictated by the type or extent of the injury.

The researchers will try to prevent any problem that could happen because of this research. You should let the researchers know at once if there is a problem and they will help you. However, TWU #4 and Texas A&M University – Commerce do not provide medical services or financial assistance for injuries that might happen because you are taking part in this research.

<u>Benefits & Results</u>
You will gain access to information about your cardiorespiratory responses to exercise on an anti-gravity treadmill and land treadmill. You will also gain information regarding your estimated maximal oxygen consumption. Your participation in the study will provide you with the opportunity to run on the Alter-G treadmill. You will be provided your results at the conclusion of the fourth exercise session. You may also request a copy of the study's abstract presenting overall study data and conclusions. If you would like to request the abstract, please provide your email address at the end of the consent form for the abstract to be sent.

<u>Voluntary Participation and Withdrawal</u>
You are voluntarily making a decision whether or not to participate in this research study. You may withdraw from the study at any time without penalty. Your signature certifies that the content and meaning of the information on this consent form have been fully explained to you and that you have decided to participate having read the information presented.

<u>Questions Regarding the Study</u>
You will be given a copy of this signed and dated consent form to keep. If you have any questions about the research study you should ask the researchers; their phone numbers are at the top of this form. If you have

Approved by the
Texas Woman's University
Institutional Review Board
Approved: March 24, 2018

____
Participant Initials

questions about your rights as a participant in this research or the way this study has been conducted, you may contact the Texas Woman's University Office of Research and Sponsored Programs at 940-898-3378 or via e-mail at IRB@twu.edu.

____ ________________

Signature of Participant Date

____

Name of Participant (Printed)

* If you would like to request the abstract, please provide your email address below for the abstract to be sent to you.

Email: ________________________________

APPENDIX C

Health History Questionnaire

TEXAS WOMAN'S UNIVERSITY
Health History Questionnaire
For a Study Entitled:
Physiological Responses to Running on a Land and Anti-gravity Treadmill

Directions. The purpose of this questionnaire is to enable the investigators to evaluate your health status and determine eligibility for participation in this study. Please answer the following questions to the best of your knowledge. All information given is **CONFIDENTIAL.**

Name:____ Age: _____ Date of Birth: __________

MEDICAL HISTORY

Have you been diagnosed within the past year with any of the following conditions?

Cardiovascular conditions _____ Yes _____ No

Asthma/breathing difficulty _____ Yes _____ No

Metabolic conditions _____ Yes _____ No

Muscle or joint conditions _____ Yes _____ No

Have you sustained any musculoskeletal injuries in the last 6 months?

______ Yes ______ No

If yes, list injuries ____

____

____

Do you know of any physical or mental condition that would prevent you from safely participating in this study?

____

____

Please list any prescribed / non-prescribed medications that you are currently taking.

____

____

EXERCISE HISTORY

Do you run as a form of exercise? ______ Yes ______ No

How long have you been running consistently (months or years)? ___________________

How many miles per week do you run? _____________

Do you participate in other forms of exercise? ______ Yes ______ No

If yes, list the type of activity, duration, and frequency: ______________________________________

____

____

Recommendation for Participation

____ No exclusion criteria presented. Subject is ***cleared*** to participate in the study.

____ Exclusion criteria may be present. A physician release form needs to be obtained before subject can be cleared for participation in the study

____ Exclusion criteria is/are present. Subject is ***not cleared*** to participate in the study.

PI Signature: ____________________________________ Date: _________________________

APPENDIX D

Participant Recruitment Flyer

Research Participants Needed
Physiological Responses to Running on a Land and Anti-gravity Treadmill

We are looking for trained runners, FEMALES and MALES!

Individuals who are 18 to 45 years old, healthy, and run 15 miles/week for the last 3 months are eligible for this study.

Benefits of Participation:

- cardiorespiratory responses to exercise on an Alter-G and land treadmill
- estimated VO2 max
- opportunity to run on the Alter-G treadmill

If you are eligible and interested, please contact:

Sarah Mitchell
Field House 210, 903-886-5543
Smitchell14@twu.edu or
Sarah.Mitchell@tamuc.edu

This study involves FOUR visits to the laboratory!

Participation is voluntary and individuals may discontinue participation at any time.
There is a potential risk of loss of confidentiality with any email, downloading, and internet transactions

APPENDIX E

Data Collection Sheets

ID					Date		
Age		DOB:			AGT shorts size		
Weight	lbs		kg		AGT chamber height		
Height							
Ethnicity							
Resting HR							
sitting 5 min							
65-70%	220						
95-100%		-age					
				100%HRR			
		-RHR					
		----→		----→			
	x 0.65		x 0.7		x 0.95		
		+ RHR				+ RHR	
65% HRR		70%HRR		95%HRR			
Submax test	58.687 + (7.520 x gender [M=1; F=0]) + (4.334 x mph) - (0.211 x kg) - (0.148 x HR) - (0.17 x age)						
	58.687 + (7.520 x _________) + (4.334 x _____) - (0.211 x _____) - (0.148 x ____) - (0.17 x ___)						
		ml/kg/min					
Stage 1	3 min self-paced walk						
Stage 2	self-paced jog at 4.3 - 7.5 mph for 3 min or until steady state (30 sec, less than 3 bpm change)						
	walk speed		HR				
	jog speed		HR				
65-70% HRR	70% AGT	90% AGT	ST	95-100% HRR (ST)	run 5min; HR steady in min 3-5 or for 2 min with HR in target range		
					15 min rest between each one		

ID					Date				
Age		DOB:			AGT shorts size				
Weight	lbs		kg		AGT chamber height				
Height					Cosmed face mask				
Ethnicity									
Resting HR					70%AGT	90%AGT	ST		
65-70% HRR			95-100%HRR			2 min self-paced walk/jog			
speed			speed			30 min 65-70% HRR			
						To Exhaustion 95-100% HRR			
						2 min cool down 2.0mph			

	Cosmed Time	**VO2 ml/kg/min**	**VO2 L/min**	**HR bpm**	**RER**	**RPE**	**Lactate mmol/l**	**EE kcal**	**TTE min**
0 min									
5 min									
10 min									
11 min									
12 min									
13 min									
14 min									
15 min									
25 min									
26 min									
27 min									
28 min									
29 min									
30 min									
Fatigue									

Notes

APPENDIX F

Raw Data

Participant Demographics

Id	Gender	Age (years)	Weight (kg)	Height (cm)	BMI (kg/m^2)	Estimated VO_2 (ml/kg/min)	Mileage (mi/wk)	65% HHR (bpm)	70% HRR (bpm)	95% HHR (bpm)	100% HRR (bpm)
001	0	34	69.00	167.64	24.55	41.19	16	150	155	181	186
002	1	21	89.32	172.72	29.94	44.92	15	154	160	193	199
003	1	21	57.27	172.72	19.20	60.41	15	155	161	193	199
004	1	24	68.63	185.42	19.96	61.98	70	145	152	189	196
005	0	21	64.73	167.64	23.03	47.96	15	148	156	192	199
006	0	21	59.18	168.91	20.74	46.13	45	150	157	192	199
007	0	20	45.68	159.39	17.98	52.09	55	152	159	193	200
008	0	21	89.91	179.07	28.04	43.68	18	151	158	192	199
009	0	18	61.00	168.91	21.38	47.35	30	151	158	195	202
011	1	19	66.36	170.18	22.91	60.37	55	150	158	194	201
012	1	19	64.64	165.10	23.71	59.80	40	147	155	193	201
013	0	25	80.36	177.80	25.42	42.71	15	145	152	188	195

70% AGT

Id	Speed 70% [65-70% HRR] (mph)	Speed TTE run (mph)	VO2_5min _70%	VO2_15min _70%	VO2_30min _70%	VO2_TTE _70%	30 min - VCO2 (ml/kg /min)	70%_ TTE - VCO2	VO2peak _70%	RER_5min _70%	RER_15 min_70 %	RER_30 min_70 %	RER_TTE _70%
001	5.4	8.1	20.82	19.88	21.82	27.99	22.59	28.50	29.41	0.99	1.08	1.04	1.02
002	5.8	7.1	20.50	19.18	20.80	23.13	18.10	20.82	25.01	0.86	0.87	0.87	0.90
003	7.7	12.0	37.75	35.20	35.03	53.15	31.18	50.74	54.83	0.94	0.93	0.89	0.96
004	10.6	12.0	30.90	31.67	32.63	37.44	28.10	36.10	39.16	0.87	0.89	0.86	0.96
005	6.8	8.7	26.94	28.13	28.79	33.94	24.49	28.68	36.76	0.89	0.87	0.85	0.85
006	6.6	9.0	22.57	24.64	23.23	30.42	18.59	26.13	32.18	0.79	0.81	0.80	0.86
007	8.3	10.2	23.30	23.37	24.04	33.30	20.67	28.91	34.29	0.86	0.87	0.86	0.87
008	8.1	10.1	33.12	35.94	33.66	41.05	20.78	26.51	41.66	0.74	0.82	0.79	0.82
009	7.5	9.4	17.81	17.72	17.16	26.88	15.80	25.66	29.66	0.92	0.94	0.92	0.95
011	8.8	11.0	29.23	35.08	35.00	45.88	29.25	39.91	48.29	0.90	0.87	0.84	0.87
012	8.5	12.0	35.03	36.87	37.55	54.33	28.31	44.40	55.13	0.81	0.75	0.75	0.83
013	9.0	10.5	19.69	25.06	28.69	37.30	24.89	32.76	37.30	0.90	0.93	0.87	0.88

Id	HR_5min _70%	HR_15min _70%	HR_30min _70%	HR_TTE _70%	HRpeak_ 70%	RPE_15min _70%	RPE_30mi n_70%	RPE_TTE _70%	TTE_ 70%	Total EE _70%	30min EE _70%	Lactate _70%
001	151	153	158	174	177	10	10	19	9.90	306	216.00	13.3
002	142	145	150	149	162	8	9	20	10.78	360	254.00	24.8
003	142	150	160	201	201	11	11	19	5.43	369	292.00	24.2
004	126	147	157	175	175	7	13	14	10.05	435	309.00	2.1
005	151	158	169	192	192	11	11	20	43.15	717	251.00	14.9
006	143	153	159	190	190	6	7	13	30.05	459	200.00	1.4
007	125	135	154	191	191	6	6	19	42.22	170	158.00	24.6
008	134	149	162	173	173	13	16	20	2.72	376	344.00	19.0
009	119	131	141	179	179	7	6	15	12.72	263	163.00	18.7
011	111	128	128	160	163	13	13	19	5.47	388	312.00	5.3
012	134	140	144	192	192	12	12	15	12.27	528	334.00	7.9
013	118	131	153	180	180	11	15	19	7.97	387	281.00	2.0

90% AGT

Id	Speed 90% [65-70% HRR] (mph)	Speed TTE run (mph)	VO2_5 min_90 %	VO2_15 min_90 %	VO2_30min _90%	VO2_TTE _90%	VO2peak _90%	30 min - VCO2 (ml/kg/min)	90%_TTE - VCO2	RER_5 min_9 0%	RER_15 min_90 %	RER_30 _90%	RER_TTE _90%
001	4.9	8.1	16.41	20.07	26.02	34.74	36.92	22.28	30.85	0.85	0.87	0.86	0.89
002	5.4	7.1	24.26	21.98	22.52	25.46	28.83	20.74	22.99	0.89	0.94	0.92	0.90
003	7.4	12.0	32.92	31.30	33.62	44.76	45.86	30.65	47.88	0.88	0.90	0.91	1.07
004	10.2	12.0	39.06	42.18	41.89	46.39	48.85	35.53	41.86	0.90	0.92	0.85	0.90
005	6.2	8.7	22.98	25.29	25.05	32.27	36.08	19.71	27.37	0.84	0.86	0.79	0.85
006	6.0	9.0	26.64	27.73	26.19	33.69	36.18	21.62	34.45	0.86	0.87	0.83	1.02
007	7.3	10.2	29.33	29.62	27.82	39.41	43.17	23.82	34.35	0.93	0.89	0.86	0.87
008	7.1	10.1	34.79	38.25	37.54	43.38	43.38	23.86	28.64	0.82	0.86	0.81	0.84
009	6.5	9.4	24.85	27.29	28.40	44.06	44.06	22.29	37.63	0.79	0.80	0.78	0.85
011	7.8	11.0	33.17	35.01	37.63	52.90	52.90	30.30	45.13	0.86	0.78	0.81	0.85
012	7.5	12.0	42.07	40.53	41.27	64.87	64.87	31.45	57.18	0.78	0.79	0.76	0.88
013	7.2	10.5	23.42	23.58	24.79	36.91	36.91	21.11	35.20	0.88	0.91	0.85	0.95

Id	HR_5min _90%	HR_15min _90%	HR_30min _90%	HR_TTE _90%	HRpeak _90%	RPE_15 min_90 %	RPE_30 min_90 %	RPE_TTE _90%	TTE_ 90%	Total EE _90%	30min EE _90%	Lactate _90%
001	147	154	168	179	183	11	11	19	6.50	290	214.00	22.5
002	148	155	162	166	178	8	9	19	10.12	415	296.00	20.4
003	148	156	161	197	197	10	11	19	5.18	324	264.00	23.8
004	143	157	169	192	192	9	13	19	15.05	636	400.00	24.0
005	145	158	167	191	192	11	11	20	20.52	436	220.00	10.4
006	116	172	178	200	200	9	9	20	10.03	324	225.00	7.7
007	147	155	167	194	194	6	6	17	15.53	338	199.00	13.0
008	135	151	161	173	173	12	14	19	1.53	383	363.00	7.4
009	150	153	167	189	189	10	11	15	4.38	282	236.00	9.1
011	132	140	149	178	178	11	12	19	2.73	373	329.00	4.0
012	139	146	151	193	193	10	10	16	5.85	484	382.00	11.9
013	124	134	151	181	181	12	15	17	2.63	318	286.00	6.5

Land Treadmill

Id	Speed ST [65-70% HRR] (mph)	Speed TTE run (mph)	VO2_5 min_ST	VO2_15 min_ST	VO2_30 min_ST	VO2_TT E_ST	VO2peak _ST	30 min - VCO2 (ml/kg/ min)	ST_TTE - VCO2	RER_5 min_ST	RER_15 min_ST	RER_30 min_ST	RER_TTE _ST
001	4.2	8.1	22.46	23.39	21.27	35.58	37.27	18.24	39.33	0.89	0.87	0.86	1.11
002	4.1	7.1	20.96	22.08	29.94	33.66	34.54	20.86	34.15	0.88	0.86	0.84	1.01
003	7.0	12.0	43.48	42.22	40.29	51.50	51.50	39.20	60.55	0.93	0.95	0.97	1.18
004	8.7	12.0	48.19	48.87	53.30	64.92	64.92	41.84	58.48	0.81	0.81	0.79	0.90
005	5.2	8.7	26.83	27.95	30.27	45.91	45.91	25.60	47.92	0.88	0.86	0.85	1.04
006	5.1	9.0	29.68	28.09	28.07	47.37	47.37	20.63	45.03	0.76	0.79	0.74	0.95
007	5.6	10.2	30.95	32.22	32.76	48.00	48.40	26.76	53.38	0.87	0.84	0.82	1.11
008	5.4	10.1	37.69	37.81	40.38	50.30	50.30	26.81	36.00	0.85	0.86	0.85	0.91
009	5.3	9.4	28.18	30.13	31.59	39.86	39.86	26.93	40.85	0.89	0.89	0.85	1.02
011	7.4	11.0	45.65	44.46	43.12	54.65	54.65	34.73	50.12	0.85	0.80	0.81	0.92
012	6.5	12.0	34.55	43.60	41.40	57.73	57.73	34.70	61.83	0.84	0.84	0.84	1.07
013	5.8	10.5	26.08	29.26	31.97	33.67	33.67	29.24	32.68	0.91	0.95	0.92	0.97

Id	HR_5min _ST	HR_15min _ST	HR_30min _ST	HR_TTE _ST	HRpeak _ST	RPE_15min _ST	RPE_30min _ST	RPE_TTE _ST	TTE _ST	Total EE _ST	30 min EE _ST	Lactate _ST
001	146	153	169	186	186	10	11	19	2.22	244	223.00	21.1
002	143	156	162	187	189	7	9	20	5.83	366	289.00	24.6
003	164	171	182	200	200	10	11	19	1.48	363	343.00	12.5
004	154	167	177	191	191	12	14	20	1.98	521	483.00	7.4
005	160	165	168	195	195	11	11	20	4.03	316	264.00	23.8
006	122	160	166	198	198	7	7	18	5.05	293	233.00	12.1
007	151	161	173	196	196	7	7	18	2.77	232	208.00	12.8
008	145	151	162	178	178	12	14	19	1.38	404	382.00	6.9
009	147	161	168	169	169	8	8	16	1.22	275	259.00	22.5
011	146	154	153	182	182	14	14	19	1.07	434	410.00	5.1
012	141	157	159	190	190	11	12	15	1.43	412	388.00	11.6
013	143	160	176	189	189	13	15	19	0.58	358	345.00	12.4