Do running kinematics change on the Alter-G treadmill?

Brittany LaVaute

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Do Running Kinematics Change on the Alter-G Treadmill?

by

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

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ABSTRACT

The Alter-G lower body positive pressure treadmill, also known as the antigravity treadmill, provides a unique means of exercising for rehabilitation patients and low-impact training in athletes. The purpose of this study was to examine the interaction effect of four different treadmill weighted conditions and three different running velocities (2.68 m s\(^{-1}\), 3.13 m s\(^{-1}\), and 3.58 m s\(^{-1}\)) on the kinematic variables of step length, step rate, contact time, and flight time on the Alter-G treadmill (AG) and on the regular treadmill (TM). Fifteen participants completed two separate days of testing. All individuals ran at four different conditions (100%, 80%, 60%, and 40%) on the antigravity treadmill and once on the regular treadmill. The results indicated that the four kinematic variables were significantly different among the treadmill-weighted conditions and between all three running velocities. However, there were no significant differences in the running kinematics between the regular treadmill and the 100% condition on the Alter-G treadmill. In conclusion, practitioners can imply the results from this study when determining exercise protocols for rehabilitation patients, as well as training protocols for athletes. This could benefit physicians, therapists, and coaches who may be interested in using the Alter-G treadmill for treatment or exercise.
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CHAPTER 1
INTRODUCTION

The Alter-G lower body positive pressure treadmill, also known as the antigravity treadmill, provides a unique means of exercising to individuals, especially to those who are obese, experiencing lower extremity injuries, or rehabilitating from other conditions. The machine was designed with the objective of decreasing the stress on joints, ligaments, and tendons during walking and running (Raffalt, Hovgaard-Hansen, & Jensen, 2013) by decreasing the ground reaction forces on the user (Draovitch, Maschi, & Hettler, 2012). The treadmill is connected to an air-filled pressure chamber that surrounds the body from the waist down and body weight can be supported from 0% to as much as 80% (Liem et al., 2013). The user wears a pair of neoprene shorts, which zip around the waist and attach to the air-filled pressure chamber. Once secured into the machine, the treadmill is then calibrated, and body weight and speeds can be adjusted accordingly.

The antigravity treadmill may be a useful tool for therapy when attempting to return to activity following an injury. This can be achieved because the machine has been shown to preserve gait mechanics while reducing lower extremity ground reaction forces in postoperative patients (Liem et al., 2013). Previous studies have shown that vertical ground reaction forces have a tendency to decrease with increasing body weight support and decrease linearly with decreasing velocities (Raffalt, Hovgaard-Hansen, & Jensen, 2013; Grabowski, 2010; Grabowski & Kram, 2008). Raffalt et al. (2013) found that step frequency and contact time decreased, where as step length and flight time increased when body
weight support was reduced while running on the antigravity treadmill. Grabowski and Kram (2008) determined that contact time and stride frequency do change somewhat with body weight support; however, they concluded that running kinematics on an antigravity treadmill are much more comparable to overground running than in other rehabilitative methods such as deep-water running. They found that peak vertical ground reaction forces could be reduced when running at faster speeds and aerobic capacity could still be obtained.

Other methods for reducing some of the treadmill user’s weight have disadvantages such as interference with normal gait, discomfort, need for upper body strength, and difficulty in accurately modulating loads (Liem et al., 2013). Harness systems may not be applicable for extending rehabilitation and training due to discomfort and impedance on circulation (Grabowski, 2010). Therefore, the antigravity treadmill has become another method for rehabilitation because it provides individuals with the option to continue training by limiting the impact on an injured area as well as maintaining cardiovascular activity.

Grabowski (2010) concluded that the antigravity treadmill could reduce the forces acting on the musculoskeletal system while maintaining metabolic demand and kinematic patterns during walking. However, limited research has been conducted on specific biomechanical variables while running on the antigravity treadmill. Further studies are needed to determine ways in which this method impacts the mechanics of running. This information is significant because it can help demonstrate the benefits of using the antigravity treadmill during training and for rehabilitation purposes such as lower limb injuries, strokes, and other sicknesses that may have impaired walking or running abilities.
Statement of the Problem

There has been limited research completed on the biomechanics of running on the Alter-G antigravity treadmill. Acute and overuse injuries are common among individuals; rehabilitation tools, such as the antigravity treadmill can help increase return to activity following an injury, but further research is needed.

Purpose of the Study

The purpose of this study was to examine the interaction effect of four different treadmill weighted conditions and three different running velocities on the kinematic variables of step length, step rate, contact time, and flight time on the Alter-G treadmill (AG) and on the regular treadmill (TM).

Hypotheses

The first hypothesis was that the four running kinematic variables would not be significantly different between the four treadmill-weighted conditions (Alter-G treadmill 100%, 80%, 60%, and 40% of body weight). The second hypothesis was that the four running kinematic variables would not be significantly different between the regular treadmill and the 100% condition on the Alter-G treadmill. It was also hypothesized that the four running kinematic variables would be significantly different between velocities (2.68 m s⁻¹, 3.13 m s⁻¹, and 3.58 m s⁻¹). These hypotheses are the same for all four dependent variables (step length, step rate, contact time, and flight time).
Delimitations

The participants used in this study were college students. Biomechanical measurements were collected. The biomechanical factors that were examined are step length, step rate, contact time, and flight time; ground reaction forces were not measured because the Alter-G treadmill doesn’t contain a force platform.

The participants were tested under four antigravity treadmill conditions (100%, 80%, 60%, and 40%). Biomechanical measurements were also obtained on a standardized treadmill. For each condition, each participant ran at three different speeds: 2.68 m s$^{-1}$, 3.13 m s$^{-1}$, and 3.58 m s$^{-1}$. These speeds were selected because a purpose of the study was to examine how gait changes at specific speeds, not at relative speeds. Each participant ran for 45-second intervals to establish steady state; each running speed was interspersed with 30-second walks.

Limitations

The vinyl window of the Alter-G may have affected the accuracy of the measurements of step length. For some participants, identification of the first frame of footstrike was difficult to identify since the vinyl window limits the view of the subject’s lower extremities.

Assumptions

It was assumed that the parameters displayed on the Alter-G control panel were accurate. These parameters included the treadmill belt speed, the treadmill surface incline, and the percent of body weight supported by the treadmill surface when a user was stationary on the treadmill. It was also assumed that the treadmill belt speed was constant at each treadmill speed setting.
Definitions

*Step length*  
horizontal distance between the point of touchdown of one foot (head of second metatarsals) to that of the following touchdown for the opposite foot (Hunter, Marshall, & McNair, 2004).

*Step rate*  
the number of steps taken per second

*Contact time*  
the duration of time from touchdown to takeoff of one step; the time during which the runner is in contact with the treadmill belt during a step

*Flight time*  
the duration of time from takeoff to touchdown of one step; the time during which the runner is not in contact with the treadmill belt during a step

*Takeoff*  
the instant when the foot is no longer in contact with the treadmill belt

*Touchdown*  
the instant when the foot first makes contact with the treadmill belt

Significance of the Study

The significance of this study was to determine if gait mechanics are affected when running at different body weight percentages on the antigravity treadmill and if this can be used for individuals as another method for rehabilitation. If gait parameters were preserved, then this is may be an effective device for rehabilitation and training. The antigravity treadmill could be useful for individuals with lower limb injuries, overuse injuries, strokes, and other sicknesses that may have impaired walking or running abilities.
CHAPTER 2
LITERATURE REVIEW

The purpose of this study was to examine the interaction effect of different treadmill weighted conditions and three different velocities on the running mechanics of step length, step rate, contact time, and flight time on an Alter-G treadmill (AG) and on the regular treadmill (TM). There has been limited research completed on the biomechanics of running on the antigravity treadmill. This is significant because it can help determine effective methods for rehabilitation and training. The review of the literature includes the comparison of running on a treadmill and overground running, characteristics and benefits of the antigravity treadmill, variables measured on the antigravity treadmill, and rehabilitation on the antigravity treadmill.

**Treadmill Running vs. Overground Running**

Treadmills are commonly used in research to analyze the kinematics and kinetics of walking and running. It has been often debated if a treadmill is a valid instrument to stimulate the kinematics of human locomotion during overground running (Nigg, De Boer, & Fisher, 1995). Running mechanics may be altered for a variety of reasons. The running style of the individual, the type of shoe worn, and the individual’s familiarity or experience could all be factors that may affect the results of the mechanics; therefore, the question of whether the results obtained from treadmill studies are transferable to an overground running scenario continues to be a common interest of researchers (Wank, Frick, & Schmidtbleicher, 1998).
Treadmills have been commonly used for training. However, researchers have become interested in using instrumented treadmills as a means for evaluating the biomechanics of running. Wank et al. (1998) compared the kinematics and muscle activities in overground and treadmill running. Overground running was performed on an indoor track and the kinetics of the movement were recorded and analyzed by two high-speed video cameras under both conditions. Results indicated that the step frequency was greater and the step length was shorter when running on the treadmill. The contact time was also shorter. The EMG muscle activity was found to be similar under both conditions. The findings of this study showed that kinematic variables changed from overground to treadmill running (Wanke et al., 1998).

The comparison of both kinematics and kinetics of treadmill and overground running have been investigated. Riley et al. (2008) compared the two parameters and discovered that the trajectories of treadmill and overground gait were similar. However, when running on an instrumented treadmill, stride time and stride length were found to be significantly shorter, and the peak propulsive anterior and peak medial GRF were significantly smaller (Riley et al., 2008). Therefore, the researchers concluded that treadmill-based analyses of running mechanics are comparable to overground running measures, but they are not directly correspondent.

Elliott and Blanksby (1976) examined a cinematographic analysis of overground and treadmill running in males and females. The researchers looked at four biomechanical variables: support phase, non-support phase, stride length, and stride rate. Jogging velocities were considered to be between 3.33-4.78 m s\(^{-1}\) and 3.45-4.80 m s\(^{-1}\) respectively; running velocities were classified to be between 4.82-6.2 m s\(^{-1}\) and 4.85-5.76 m s\(^{-1}\). Subjects self-
selected their speeds during overground running, and those speeds were matched to determined what speeds they would use on the treadmill. Results demonstrated no significant differences for males or females at jogging velocities, but significant differences were shown at running velocities (4.82-6.2 m s⁻¹ for males and 4.85-5.76 m s⁻¹ for females). Stride length decreased, stride rate increased, and the time period of the non-support phase was also significantly less for both males and females when running on a treadmill compared to overground running (Elliott & Blanksby, 1976).

The authors of Fredericks et al. (2015) compared the effects of running at various speeds on foot strike pattern, stride length, knee angles and ankle angles in traditional, minimalist, and barefoot running conditions. Different speeds and types of footwear have both been shown to have an effect on biomechanics and injury. Subjects ran at four different speeds during each visit; there were a total of four separate visits, and a different shod condition was completed each test day. Video data collection was recorded of the kinematic information. The results demonstrated that footwear, but not speed, had an influence on foot strike pattern (Fredericks et al., 2015). Footwear type is another factor that contributes to differences in running mechanics and lower extremity injuries.

**The Antigravity Treadmill**

An Alter-G treadmill, also known as an antigravity treadmill, is a newer device used for loading and unloading lower extremities during walking and running (Cutek et al., 2006). There has been limited research conducted on the kinematics of running on an antigravity treadmill. National Aeronautics and Space Administration (NASA) originally designed the antigravity treadmill as a mechanism for astronauts to exercise while in space (Liem, Truswell, & Harrast, 2013). The treadmill is connected to an air-filled pressure
chamber that surrounds the body from the waist down and body weight can be supported from 0% to as much as 80% (Liem et al., 2013). The user wears a pair of neoprene shorts, which zip around the waist and attach to the air-filled pressure chamber. Once secured into the machine, the treadmill is then calibrated, and body weight and speeds can be adjusted accordingly. The device has become a useful tool today for rehabilitation and training purposes.

This device was designed with the objective of decreasing the stress on joints, ligaments, and tendons during walking and running (Raffalt, Hovgaard-Hansen, & Jensen, 2013). Another primary goal of the treadmill was to decrease ground reaction force and the amount of load transmitted through tissues of the lower limbs (Draovitch, Maschi, & Hettler, 2012). There is air in the pressure-controlled chamber that lifts the individual up from the treadmill, which allows for lower impact forces to be achieved. An increase in the axial force (un-weighting) decreases the overall ground reaction force (Draovitch et al., 2012). Other methods for reducing some of the treadmill user’s weight have disadvantages such as interference with normal gait, discomfort, need for upper body strength, and difficulty in accurately modulating loads (Liem et al., 2013). Harness systems may not be applicable for extending rehabilitation and training due to discomfort and impedance on circulation (Grabowski, 2010). Therefore, the antigravity treadmill has become another method for rehabilitation because it provides individuals with the option to continue training by limiting the impact on an injured area as well as maintaining cardiovascular activity.

Draovitch et al. (2012) discussed the benefits and different ways in which unloaded treadmills can be used. The antigravity treadmill may be a useful tool for therapy when attempting to return to the sport phase following an injury. This can be achieved because the
device has been shown to preserve gait mechanics while reducing lower extremity ground reaction forces in postoperative patients (Liem et al., 2013). Once the patient is able to tolerate 85% weight bearing, it has been suggested to make the transition from the antigravity treadmill to full weight bearing activity (Saxena & Granot, 2015). It has been shown to enhance conditioning and performance, increase metabolic demand, and decrease lower extremity load. Also, “over speed” training has been suggested to improve cardiovascular fitness on an unloaded treadmill (Draovitch et al., 2012). Therefore, some individuals might use this machine during training instead of overground running.

**Variables Measured on the Antigravity Treadmill**

Biomechanical and physiological factors, muscle activity, and EMG amplitude have all been measured using the antigravity treadmill. Raffalt, Hovgaard-Hansen, and Jensen (2013) investigated VO$_2$ max, respiratory response, and vertical ground reaction forces on an Alter-G treadmill. The authors aimed to determine if VO$_2$ max was achievable while running with reduced body weight, how vertical ground reaction forces changed during high running speeds with less body weight, and how respiratory responses were affected while running on an antigravity treadmill. Twelve well-trained runners were tested over the course of three days. The first and second day consisted of VO$_2$ max tests on a regular treadmill and on the Alter-G treadmill. The third day was a submaximal steady state running test at 2.78 m s$^{-1}$, 3.89 m s$^{-1}$, and 5.00 m s$^{-1}$, and high speed running at 5.56 m s$^{-1}$ and 6.11 m s$^{-1}$ at 100%, 75%, 50%, and 25% of body weight on the device (Raffalt et al., 2013). During the VO$_2$ max tests, VO$_2$ max, maximal heart rate, ventilation, breathing rate, end respiratory exchange ratio, end blood lactate concentration, end RPE, and time to exhaustion were
measured. During the submaximal tests, vertical ground reaction force, contact time, flight time, time for leg repositioning, step frequency, and step length were measured.

The results of Raffalt et al. (2013) showed no significant differences between the regular treadmill and the antigravity treadmill in relation to VO\textsubscript{2} max, maximal heart rate, ventilation, breathing rate, end respiratory exchange ratio, and end blood lactate concentration. However, time to exhaustion on the antigravity treadmill increased significantly compared to the regular treadmill. Body weight reduction and increased running speeds demonstrated a decrease in oxygen uptake, heart rate, ventilation, and mean vertical ground reaction force. Breathing frequency remained constant with decreasing body weight. Also, step frequency and contact time decreased, where as step length and flight time increased when body weight support was reduced. The authors suggested that the Alter-G treadmill is a relevant tool for rehabilitation training and low-impact training for athletes due to the combination of low vertical ground reaction forces, high aerobic capacity, and a near-normal movement pattern (Raffalt et al., 2013).

Another study tested how changes in velocity and weight support influenced metabolic power and ground reaction forces when walking on an antigravity treadmill (Grabowski, 2010). Ten subjects walked on a force-measuring treadmill enclosed in a chamber. Metabolic rates, stance phase durations, and ground reaction forces were measured. Subjects randomly walked at 3 different velocities (1.0 m s\textsuperscript{-1}, 1.25 m s\textsuperscript{-1}, 1.5 m s\textsuperscript{-1}) at 5 body weight percentages (100%, 85%, 75%, 50%, and 25%). As speed increased and body weight remained constant, metabolic demands were greater; when subjects walked at a constant speed and body weight was reduced, metabolic power decreased (Grabowski, 2010). Walking faster with lower body weight resulted in reduced peak vertical ground
reaction forces. No significant changes were shown in stride frequency, and contact time was only slightly shorter at smaller body weight percentages. Grabowski (2010) therefore concluded that a training device, such as the antigravity treadmill, could reduce the forces acting on the musculoskeletal system while maintaining metabolic demand and kinematic patterns during walking.

Grabowski and Kram (2008) also examined how changes in velocity and weight support affected ground reaction forces and metabolic power. However, running was examined instead of walking. Similar to the research design by Grabowski (2010), an antigravity treadmill was used, which was referred to as the G-trainer in this study. The protocol was different than the previous study. Ten healthy recreational runners were randomly assigned to run at 3.0 m·s\(^{-1}\) at 75%, 50%, and 25% of body weight; 4.0 m·s\(^{-1}\) at 100%, 75%, 50%, and 25% of body weight; and 5.0 m·s\(^{-1}\) at 50%, and 25% of body weight. The treadmill contained a force platform to measure ground reaction forces for all trials. Metabolic rates, stride frequency, and contact time were also collected. Oxygen consumption rates and carbon dioxide production were collected to calculate gross metabolic power. Results determined that ground reaction forces increased linearly when velocity was increased. Also, ground reaction forces decreased with increasing body weight support during all speed conditions. The results of Grabowski and Kram (2008) demonstrated that a decline in either velocity or body weight demanded less metabolic power.

Grabowski and Kram (2008) discussed the advantages of the antigravity treadmill. Their results determined that contact time and stride frequency do change somewhat with body weight support; however, it was concluded that running kinematics on a this device are
much more comparable to overground running than in other training methods such as deep-water running (Grabowski & Kram, 2008). The findings of this study showed that peak vertical ground reaction forces could be reduced when running at faster speeds with decreased body weight and aerobic capacity was maintained. Therefore, the authors concluded that the antigravity treadmill might be beneficial for people during training and rehabilitation (Grabowski & Kram, 2008).

It has been reported that ground reaction forces are reduced as body weight is decreased in previous studies (Cutuk et al., 2006; Grabowski & Kram, 2008). Another area of interest is how the antigravity treadmill affects muscle activity. Mercer, Applequist, and Masumoto (2013) aimed to determine if muscle activity would continue to decrease with reductions in body weight; the researchers also looked to see if muscle activity would increase across speeds at each body weight. Electromyography (EMG) was used to measure muscle activity of four specific muscles, which included biceps femoris (BF), rectus femoris (RF), tibialis anterior (TA), and medial gastrocnemius (GA). Subjects were blinded and repeated three different self-selected speed tests, which were recorded and used when determining the running speeds on the antigravity treadmill. Subjects completed 15 running conditions at different body weight settings (100%, 50%, 40%, 30%, and 20%) at three speeds (100%, 115%, and 125% of preferred speed). Running time consisted of about 1.5-2 minutes per condition with rest in between. EMG data was collected for 1 minute during each trial (Mercer et al., 2013).

Overall, the findings of Mercer et al. (2013) determined that muscle activity increased with speed and decreased with body weight reductions. The significance of this study is that runners should be able to run at faster speeds at reduced body weight because
the activity on the key lower extremity muscles is decreased when running on an antigravity treadmill (Mercer et al., 2013). Therefore, this can contribute to another type of training method for long distance runners.

An increase in EMG amplitude may increase the risk of lower extremity injuries. Hunter, Seeley, Hopkins, Carr, and Franson (2014) investigated muscle activity changes during positive pressure treadmill running on 12 lower limb muscles at 100%, 80%, 60%, and 40% of body weight. Electromyography data were obtained for 20 seconds during each body weight phase; subjects ran for two minutes at each body weight setting in a randomized order at a speed of 4.47 m s\(^{-1}\). As body weight was reduced, most muscles demonstrated lower EMG amplitudes. However, two muscle groups didn’t show a significant decrease in muscle activation during the different conditions; these muscle groups included the hip adductors during the swing phase and the medial and lateral hamstrings during the stance (Hunter et al., 2014). The results demonstrated that using an antigravity treadmill might be beneficial during rehabilitation and during long-distance training due to the lower activation of certain lower extremity muscles (Hunter et al., 2014).

Partial body weight reduction has been shown to not have a major impact on physiological responses when participating in aerobic activity on an antigravity treadmill. Figueroa, Manning, and Escamilla (2011) found no significant metabolic differences between when running at 100%, 90%, and 80% of body weight on the device. Oxygen consumption, heart rate, blood pressure, caloric expenditure, substrate utilization, and Respiratory Exchange Ratio (RER) were all recorded at the different body weight percentages. Therefore, these results demonstrated that removal of up to 20% of body
weight does not significantly alter the metabolic responses during aerobic activity (Figueroa et al., 2011).

Another experiment measured physiological parameters at three percentages of body weight (100%, 75%, and 50%). Hoffman and Donaghe (2011) used twelve healthy adults to participate in the study. VO₂, heart rate, blood pressure, RPE, and ground reaction forces were obtained during walking and running at three different treadmill settings. Partial body weight support significantly altered standing heart rate and systolic blood pressure; diastolic and mean blood pressures were unaffected (Hoffman & Donaghe, 2011). The relationship between heart rate and VO₂ was not significantly altered, and RPE was not statistically significant among the conditions. Also, ground reaction forces were reduced with decreasing body weight during walking and running. Conflicting with the results of Grabowski and Kram (2008), partial body weight reduction did not significantly affect the relationship between maximum vertical loading rate and speed during running (Hoffman & Donaghe, 2011). Therefore, the relationship between heart rate and VO₂ demonstrated that individuals could expect a similar metabolic demand when exercising at partial body weight reduction as with unsupported exercise (Hoffman & Donaghe, 2011).

Maximal physiological and biomechanical parameters were measured during a graded running exercise test (GXT) using an antigravity treadmill and a regular treadmill (Gojanovic, Cutti, Shultz, & Matheson, 2012). Fourteen trained runners were selected to perform a GXT on a regular treadmill at 0% grade until volitional exhaustion; the same test was repeated on separate days on the Alter-G machine at 100%, 95%, 90%, and 85% of body weight in randomized order. Benchmark values were determined from the regular treadmill test (CON). The physiological outcome measures included HRmax, VO₂max, and
RPE; using a high-speed video camera, stride rate and stride length were captured and analyzed.

Results from Gojanovic et al. (2012) found no significant difference between any of the conditions for time to VO\textsubscript{2} max. For the men, HR\textsubscript{max} during 85\% body weight was found to be significantly different than the CON condition; for women, the 100\% and 90\% body weight conditions were found to be significantly different from the CON condition (Gojanovic et al., 2012). Step rate increased as body weight decreased significantly in all conditions compared with CON in men, but it did not change significantly in women. Step length was found to be higher in men under the 95\%, 90\%, and 85\% conditions, and higher in women during the 95\% and 85\% conditions; however, this was not statistically significant. Therefore, the results of this study show that the Alter-G treadmill can be used to achieve maximal aerobic capacity at different body weight settings, and a range of exercise intensities can be performed, whether the purpose of using the machine is for training or rehabilitation (Gojanovic et al., 2012).

McNeill, Kline, Heer, and Coast (2015) looked at oxygen consumption in distance runners using an antigravity treadmill. Six male participants were evaluated on the relationship between velocity and metabolic cost during body weight reduction when running on the antigravity treadmill. The first testing day consisted of a 16-minute continuous run on a regular treadmill; the run involved four stages of 4 minutes each, at speeds of 3.35 m\textsuperscript{s}\textsuperscript{1}, 3.83 m\textsuperscript{s}\textsuperscript{1}, 4.47 m\textsuperscript{s}\textsuperscript{1}, and 5.36 m\textsuperscript{s}\textsuperscript{1}. The second day included the Alter-G antigravity treadmill; this test involved the same 16-minute continuous run, but it was repeated twice. The first interval was at 60\% body weight, and the second was at 80\% body weight; a recovery period was provided for at least 45 minutes between the two 16-minute
session runs (McNeill et al., 2015). Heart rate, VO₂, and VCO₂ were measured throughout each test, while ensuring that the Respiratory Exchange Ratio (RER) did not exceed 1.00.

The results of McNeill et al. (2015) indicated that RER and HR increased with velocity and was higher with less body weight support. There was a significant difference in velocity, which demonstrated that VO₂ increased as velocity increased, and VO₂ decreased with reductions in body weight percentages. There were three primary findings in this study among elite level distance runners that were consistent with prior research; metabolic cost significantly decreases with reductions in body weight, metabolic cost significantly increases with increasing velocity, and there was an overall decrease in metabolic cost as body weight decreases (McNeill et al., 2015).

Fifteen male and female subjects participated in a study conducted by Cutuk et al. (2006), which examined the effects of unloading weight on gait mechanics and on the cardiovascular system during antigravity treadmill ambulation. Nine subjects completed the cardiovascular portion, and six participated in the gait analysis. One of the primary goals of this study was to determine if the machine is a safe rehabilitation tool for patients (Cutuk et al., 2006). Heart rate, blood pressure, brain oxygenation, blood flow velocity through the middle cerebral artery, and head skin microvascular blood flow were all collected for cardiovascular parameters. Kinematic measurements included ground reaction forces, knee and ankle sagittal range of motion, and stride length. Cardiovascular measures were observed in an upright position with changing treadmill pressures, and gait mechanics were collected during walking and running phases.

Results confirmed Cutuk et al. (2006) hypotheses that mean arterial pressure, systolic, and diastolic blood pressure do not significantly increase while standing in the
antigravity treadmill ambulating 0-50mmHg on the antigravity treadmill; also, head capillary perfusion, macrovascular circulation, and oxygenation were unchanged. Results indicated a decrease in ground reaction forces with decreased body weight and no significant changes in range of motion or stride length (Cutek et al., 2006).

These findings demonstrated minimal risks in terms of head perfusion and vascular flow (Cutek et al., 2006). Reduced ground reaction forces showed that external forces affecting the lower extremities are decreased. Also, this machine showed insignificant alterations in gait mechanics. Due to the results confirming that the antigravity treadmill maintains cardiovascular safety, gait kinematics, and decreases ground reaction forces, this device could be suggested as a safe rehabilitation tool for patients (Cutek et al., 2006).

Varying body weight conditions and Froude numbers were performed to compare two suspended treadmill devices; an antigravity treadmill and a harness system were used to analyze six different parameters (Ruckstuhl, Kho, Weed, Wilkinson, & Hargens, 2009). Four gait parameters (cadence, normalized stride length, duty factory, and leg angle touchdown), heart rate, and comfort level were collected during each trial among 12 subjects. Subjects walked at three body weight conditions (100%, 66%, and 33%) and three Froude numbers (.09, .25, and .5). The Froude number (Fr) is derived from a traditional walking model; in this study, Froude numbers were chosen to investigate slow walking (Fr= 0.09), comfortable walking (Fr= 0.25), and walk-run transition (Fr= 0.5), and treadmill speed was then calculated with that number based on a specific formula (Ruckstuhl et al., 2009).

The results of Ruckstuhl et al. (2009) indicated unloading and reductions in speed changed gait parameters. For the antigravity treadmill and harness system, cadence,
normalized stride length, duty factor, and heart rate decreased significantly with unloading; leg angle at touchdown increased significantly. A higher Froude number demonstrated a significant increase in cadence, normalized stride length, and heart rate, whereas duty factor, leg angle and comfort decreased with higher Froude numbers for both devices. Therefore, the results indicated that antigravity treadmill and the harness treadmill systems have similar walking gait patterns (Ruckstuhl et al., 2009).

Another important finding from this study was that heart rate was lower and comfort was higher during treadmill unloading ambulation when compared to the harness system (Ruckstuhl et al., 2009). The reduction in heart rate is imperative when considering exercise programs in patients with cardiovascular disease, which can be related to the results by Cutek et al. (2006). Also, the antigravity treadmill might be more comfortable than a harness system when training over a long period of time.

**Rehabilitation on the Antigravity Treadmill**

A review by Liem, Truswell, and Harrast (2013) discussed how antigravity treadmill training has been used to rehabilitate a number of conditions such as stroke, Parkinson’s disease, osteoarthritis, and lower limb injuries. The device can be used for a variety of different techniques, which include long runs, intervals, tempo runs, and recovery runs. The antigravity treadmill allows individuals to continue training during rehabilitation as well as provide another method of training for an uninjured high-mileage runner (Liem et al., 2013). The authors also mention the many benefits of training on the device. Some of these benefits included reduced stress on injured tissue and joints, maintenance of cardiorespiratory fitness, a training effect, and a potential decrease in injury risk from overtraining (Liem et al., 2013).
Lower extremity injuries are common among individuals, especially in athletes. Rehabilitation mechanisms help prevent inactivity and restore muscle strength as well as balance (Liem et al., 2013). A case study performed by Tenforde, Watanabe, Moreno, and Fredericson (2015) utilized the antigravity treadmill for rehabilitation purposes. A 21-year-old female NCAA Division I runner with a medical history of injuries was diagnosed with a pelvic stress injury. She was initially restricted from impact-loading exercises, but soon began using an antigravity treadmill for therapy. The subject returned to ground running after 8 weeks of training and rehabilitation, and by week 10, she was able to compete in the conference championship. This study represented how antigravity treadmills may serve as a beneficial treatment method for stress injuries in runners as well as aid in the time to return to activity for other athletes with lower extremity injuries (Tenforde et al., 2015).

One major advantage of the Alter-G machine is the reduction in ground reaction forces, which is favorable for individuals who are experiencing injuries such as Achilles tendinitis and plantar fasciitis (Figueroa, Manning, & Escamilla, 2011). The objective of the study conducted by Patil et al. (2013) was to determine the effectiveness of the treadmill in reducing knee forces; the authors wanted to validate this machine as a useful tool for rehabilitation following lower limb surgery. Individuals implanted with instrumented knee prostheses were tested. Tibial forces were measured at treadmill speeds between 0.67 m s\(^{-1}\) to 2.01 m s\(^{-1}\) at four different treadmill pressure settings (100%, 75%, 50%, and 25%). The force plate in the treadmill measured ground reaction forces. The results showed a consistent reduction in knee forces with an increase in chamber pressure; peak knee forces were significantly correlated with walking speed and treadmill reaction force (Patil et al., 2013). The authors demonstrated the efficacy of the antigravity treadmill; this is another study that
confirmed that the device might be an effective tool for patients following lower-extremity injuries (Patil et al., 2013).

Another study examined the use of an antigravity treadmill for rehabilitation and return to activity. Patients undergoing Achilles tendon rupture or insertion AL repair surgery were selected (Saxena & Granot, 2015). Participants were put into two different groups. Patients that were rehabilitated with the Alter-G were considered the study group; patients with the same diagnoses that didn’t use the antigravity treadmill during rehabilitation were put into the control group. The patients that used the Alter-G were able to return to running approximately 2 weeks quicker than the control group. The results from this study demonstrated that the antigravity treadmill might help increase return to activity levels (Saxena & Granot, 2015). Other types of foot and ankle surgeries could benefit from this type of rehab as well. A retrospective review of several studies that contain common foot and ankle surgeries was analyzed (Saxena, 2012). Saxena (2012) presented realistic expectations for recovery and return to sports following these injuries; evidence also suggested that tools such as the antigravity treadmill might help speed up return to activity among individuals.

Obesity can cause individuals to experience greater vertical ground reaction forces when walking or running. One study conducted by Denning, Winward, Pardo, Hopkins, and Matthew (2015) looked to determine whether body weight independently affects articular cartilage catabolism and how decreased body weight influenced cardiovascular response during walking. Cartilage oligomeric matrix protein (COMP) was measured; COMP is a noncollagenous extracellular matrix protein that interacts with collagen and other matrix components to increase structural integrity and load bearing ability of articular cartilage.
Heart rate and RPE values were also measured during data collection. The authors supported their hypothesis that walking with increased body weight directly increased articular cartilage catabolism and cardiovascular response; when body weight was decreased on the antigravity treadmill, so was the cartilage catabolism. Therefore, the antigravity treadmill could be beneficial to individuals experiencing obesity who might want to minimize knee joint load during walking (Dennin et al., 2015).

Antigravity training has been shown to improve walking capacity and postural balance in patients with muscular dystrophy (Berthelsen et al., 2015). Since there is no cure for this disease, aerobic exercise and strength training can be helpful. Berthelsen et al. (2015) designed a 10-week program for individuals with Limb-Girdle Muscular Dystrophy type 21 (LGMD21) and X-linked inherited Becker Muscular Dystrophy (BMD). The protocol involved a combination of both aerobic and strength training on an antigravity treadmill. A six-minute walking test, dynamic postural balance, and plasma creatine kinase were measured 10 weeks before training, immediately before training, and 10 weeks after training. Aerobic training consisted of interval training (1-2 minutes of exercise and 1 minute of rest); strength training involved three main exercises while standing in the antigravity treadmill with body weight support (squats, calf raises, and lunges). The results demonstrated an improvement in walking distance and an increase in time during the dynamic postural balance test. There were no changes in plasma creatine kinase levels. Therefore, the results showed that a combination of aerobic and strength training on an antigravity treadmill can improve physical function in patients with muscular dystrophy (Berthelsen et al., 2015).
Another study examined the influence of antigravity treadmill training in children with cerebral palsy (Kurz, Corr, Stuberg, Volkman, & Smith, 2011). Since cerebral palsy tends to impair gait patterns, the researchers aimed to improve walking abilities, balance, and lower extremity strength. A 6-week program was designed and subjects participated in training twice a week. Baseline and post assessments were performed on preferred walking speed, spatiotemporal kinematics, lower extremity strength, and on overall balance to assess enhancements during the training period. The results of antigravity treadmill training indicated a significant increase in preferred walking speed, which was accompanied by less time spent in the double support phase. Results demonstrated a significant improvement in BESTest scores, which indicated better overall balance; also, there was a significant increase in the overall strength of the lower extremity antigravity musculature (Kurz et al., 2011).

The results of Kurz et al. (2011) provided clinical relevance. This study suggests that antigravity treadmill training can be used to promote improvements in walking speed, balance, and lower extremity strength in children with cerebral palsy (Kurz et al., 2011). However, there was no control group to use for comparison. The findings of this study concluded that it is practical to use antigravity treadmill training to improve abilities of children with cerebral palsy, but further studies with different subtypes of cerebral palsy should be conducted to support this conclusion (Kurz et al., 2011).

Parkinson’s disease is a disorder that impairs motor ability and stability in individuals. Body weight reduction has been shown to improve performance and motor skills in people with Parkinson’s disease (Malling & Jensen, 2015; Rose, Løkkegaard, Sonne-Holm, & Jensen, 2013). Rose et al. (2013) had subjects complete an 8-week intervention program that evaluated clinical status, quality of life, and gait capacity during
antigravity treadmill training. The Movement Disorders Society-Unified Parkinson’s Disease Rating Scale (MDS-UPDRS), Parkinson’s Disease Questionnaire-39 items (PDQ-39), and the six-minute walk test were conducted as pre and post tests for the 8-week period. Results indicated significant improvements in all outcome measures; therefore, this study suggests that decreased body weight training can be beneficial in patients experiencing Parkinson’s disease (Rose et al., 2013).

Malling and Jensen (2015) also completed an 8-week training program on an antigravity treadmill for individuals with Parkinson’s disease. The researchers measured different performance parameters than Rose et al. (2013), but results exemplified similar outcomes. Balance related task performance was improved over the 8-week time period due to an increase in completion time during a sit-to-stand test and in the dynamic balance test. Therefore, both Malling and Jensen (2015) and Rose et al. (2013) demonstrated that eight weeks of training on an antigravity treadmill could improve motor performance, quality of life, and gait capacity in individuals with Parkinson’s disease.

**Summary**

Previous research has been conducted using the antigravity treadmill to analyze biomechanical and physiological factors. The treadmill supports the body in an upright position, which diminishes ground reaction forces on the lower extremity limbs. Many studies have also demonstrated the positive effects of using the machine as a means of rehabilitation. The device allows individuals to remain active during the healing period by adjusting the amount of weighted support with a variety of speeds. Also, athletes can use the antigravity treadmill to train at a lower body weight percentage while still achieving cardiovascular fitness. Future studies should continue to examine biomechanical parameters,
physiological factors, and muscle activity when running and walking on an antigravity treadmill. Further investigation can help with training and rehabilitation protocols for athletes, physicians, coaches, and therapists.
CHAPTER 3

METHODS

The purpose of this study was to examine the interaction effect of different treadmill weighted conditions and three different velocities on the running mechanics of step length, step rate, contact time, and flight time on an Alter-G treadmill (AG) and on a regular treadmill (TM). This chapter includes participant information, description of the procedures, and description of the statistical analysis of the data.

Participants

Fifteen students from the State University of New York College at Cortland were recruited to participate in this study.

Informed Consent

Each participant completed and signed an informed consent prior to participation in the study. The form contained details about the study including the purpose, procedure, risk and benefits, and IRB approval information. If participants were experiencing any lower extremity injuries at the time of data collection, then they were excluded from the study. The informed consent and IRB approval letter are shown in Appendix B and Appendix C respectively.

Variables

The independent variables were the five different treadmill-weighted conditions (100%, 80%, 60%, 40%, and regular treadmill) and the three different running velocities
(2.68 m s\(^{-1}\), 3.13 m s\(^{-1}\), and 3.58 m s\(^{-1}\)). The dependent variables were the four different running kinematic measures: step length, step rate, contact time, and flight time.

**Data Collection Setup**

The lengths of both treadmill belts were measured. The treadmill belts were then marked with 2 cm diameter circles at equal intervals on either side of the treadmill belt so that at least two intervals (three marks on each side of the belt) were visible at all times. The interval distance on the Alter-G treadmill was shorter because the vinyl window of the Alter-G treadmill reduced the length of the treadmill belt that was visible. The Alter-G treadmill belt length was 311.2 cm, and the regular treadmill belt length was 334.2 cm. Therefore, the regular treadmill belt was divided into six intervals, which were 55.7 cm each. The Alter-G treadmill belt was divided into eight intervals, which were 38.9 cm each.

Two cameras were used in this study to record the biomechanical variables of step length, step rate, contact time, and flight time. The cameras used were the Casio Exilim Pro EX-F1 and the JVC GC-PX10. The Casio camera was operated at 300 frames per second (actual frame rate: 299.7 fps) with a resolution of 512 x 384. The JVC camera was operated at 60 frames per second (actual frame rate: 59.94 fps) with a resolution of 1920 x 1080. The focal length of the zoom lens of each camera was set so that the camera’s field of view was wide enough to observe touchdown to takeoff of the same foot. The shutter speeds of both cameras were set at 1/300 of a second or faster. The camera apertures were set to their widest opening. Each camera was mounted on a tripod and positioned so that the camera’s optical axis was perpendicular to the centerline of the treadmill belt.
Three Smith Victor lamps were used to illuminate the lower extremities of the participants while they were on the treadmill. One lamp provided back lighting from the opposite side, and the other two lamps provided front lighting from the camera locations.

The participant number, treadmill speed, and weight condition were written on a white board prior to each trial. The white board was set in the cameras’ fields of view at the beginning of each trial. The white board identified the participant, weight condition, and speed in the video records of each trial when the dependent variables were later analyzed.

The video records were analyzed using the Tracker video analysis program after all trials were completed. Contact times, flight times, and step rates were measured from the Casio video records. Approximately 30 seconds into the trial, a frame of touchdown of either the right foot (Alter-G) or the left foot (regular treadmill) was identified. To compute the dependent variable of contact time, the number of frames from this frame of touchdown to frame of takeoff of the same foot were counted and divided by the frame rate (#frames/299.7fps = contact time). To compute the dependent variable of flight time, the number of frames from this frame of takeoff to the frame of touchdown of the opposite foot were counted and divided by the frame rate (#frames/299.7fps = flight time). To compute the dependent variable of step rate, the inverse of total step time (flight time plus contact time) was calculated (1/total step time = step rate). This procedure was repeated for the next step. Each pair of contact times, flight times, and step rates were averaged for each trial.

Step length was measured using the Tracker video analysis program. Either the right foot (Alter-G) or the left foot (regular treadmill) contact that occurred approximately 30 seconds into the trial was identified. Using the Tracker video analysis software, the location of a point on the shoe of the contacting foot was measured in the following manner. The
Tracker perspective filter was applied to this video frame. The marks on either side of the treadmill that identified the start of an interval were digitized, and the marks two intervals forward on either side of the treadmill were also digitized. These four marks formed the corners of a rectangle on the belt of the treadmill. When viewed from the perspective of the JVC video camera however, these marks formed the corners of a trapezoid (Figure 1). The perspective filter of the Tracker video analysis program was used to transform this trapezoid into a rectangle (Figure 2). This perspective filter also transformed the rest of the video image as well so that the position of any object on the plane of the treadmill belt could be determined relative to a line between any pair of visible markers on opposite sides of the treadmill belt.

![Image of video frame showing the trapezoid formed by the four markers prior to application of the perspective filter in the Tracker video analysis program.](image)

**Figure 1.** Video frame showing the trapezoid formed by the four markers prior to application of the perspective filter in the Tracker video analysis program.
Figure 2. The same video frame after application of the perspective filter in the Tracker video analysis program. Note that the marks on either side of the treadmill belt are now aligned with each other and that any two pairs of marks form corners of a rectangle.

After the perspective filter was applied, a reference measure was created by using the calibration stick function in Tracker. One end of the calibration stick was positioned on a marker at the left end of a two interval distance, and the other end of the calibration stick was positioned at a marker at the right end of a two interval distance. For the regular treadmill the calibration stick represented a distance of 111.4 cm. For the Alter-G treadmill the calibration stick represented a distance of 77.8 cm. The calibration stick transformed the pixel coordinates of the video frame into real world coordinates. A coordinate system was established by locating the origin at one of the interval marks on the near side of the treadmill belt with the x-axis parallel to the treadmill belt and the y-axis perpendicular to the
treadmill belt. The x-coordinate of a point on the shoe of the contacting foot was measured by digitizing that point of the shoe (Figure 3).

**Figure 3.** Perspective view in the Tracker video analysis program showing the coordinate system, x-coordinate of the contact foot, and the cursor of the digitizer on the first contact foot shoe.

After the first contact foot was digitized, the video was then advanced to a frame where the opposite foot was in contact with the treadmill and the procedure was repeated. The number of intervals between the two origin locations was multiplied by the interval distance (55.7 or 38.9 cm). The x-coordinates for the two foot contacts were either added or subtracted from this product, depending on each foot location relative to each origin. This procedure was then repeated to get the next step length. The average of these two step lengths was computed and used in the statistical analysis.
The formula used for calculating the initial step length on the regular treadmill was:

\[ SL = (55.7 \text{cm} \times \text{INT}) + (X \text{ left}) - (X \text{ right}) \]

Where,

- \( SL \) = step length
- \( \text{INT} \) = number of intervals
- \( X \text{ left} \) = x-coordinate of left foot during contact phase
- \( X \text{ right} \) = x-coordinate of right foot during contact phase

This same formula was used to calculate the next step length on the regular treadmill but the \( X \text{ left} \) and \( X \text{ right} \) coordinates were switched in the equation.

The formula used for calculating the initial step length on the Alter-G treadmill was:

\[ SL = (38.9 \text{cm} \times \text{INT}) - (X \text{ right}) + (X \text{ left}) \]

Where,

- \( SL \) = step length
- \( \text{INT} \) = number of intervals
- \( X \text{ right} \) = x-coordinate of right foot during contact phase
- \( X \text{ left} \) = x-coordinate of left foot during contact phase

This same formula was used to calculate the next step length on the Alter-G treadmill but the \( X \text{ right} \) and \( X \text{ left} \) coordinates were switched in the equation.
Design and Procedure

Anthropometric data of height, weight, age, and gender were initially collected on each participant (Table 1). A scale was used to obtain height and weight information. Age and gender were self-reported.

Table 1

Characteristics of Participants

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</tr>
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<td>+/- 10.1</td>
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<td>+/- 1.1</td>
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</table>

Each participant ran on the Alter-G treadmill and on the regular treadmill. All individuals ran on the regular treadmill first. Treadmill trials were completed over the course of two different days for each participant so that a participant was not doing both treadmill conditions on the same day. Each participant wore a pair of neoprene shorts when running on the antigravity treadmill. The neoprene shorts secured the participant into the Alter-G
treadmill via a zipper. Once the participant was zipped into the Alter-G treadmill, the machine was then calibrated.

For both treadmill conditions, each participant warmed up with 2 minutes of walking at 1.12 m\(\text{s}^{-1}\) before data collection began. The exercise protocol was the same for every participant. All individuals ran at four different conditions (100\%, 80\%, 60\%, and 40\%) on the antigravity treadmill and once on the regular treadmill. Individuals ran at three different velocities (2.68 m\(\text{s}^{-1}\), 3.13 m\(\text{s}^{-1}\), and 3.58 m\(\text{s}^{-1}\)) during each condition. Each participant ran for 45-second intervals to establish steady state; each running speed was interspersed with 30-second walks. The walking speed was 1.12 m\(\text{s}^{-1}\). The time it took to speed up the treadmill to running pace and the time it took to slow down the treadmill to walking pace was not considered in the 45-second intervals of running and the 30-second intervals of walking. A stopwatch was used to record running and walking time intervals. The stopwatch did not start until the treadmill reached the desired treadmill speed for running or walking. The video cameras began recording at start of each running interval, and ended when the treadmill speed was decreased to walking speed. The lights remained on during all running and walking intervals. The lights were turned off after the last running interval was completed. The dependent variables of step length, step rate, contact time, and flight time were then measured from the video records using the Tracker video analysis program. Table 2 shows the test protocol for each participant.
Table 2

*Test Protocol*

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<th>Condition</th>
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<th>AG 60%</th>
<th>AG 40%</th>
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<tr>
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<td>3.58 m·s⁻¹</td>
<td>3.58 m·s⁻¹</td>
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<td>30 seconds</td>
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<td></td>
<td>1.12 m·s⁻¹</td>
<td>1.12 m·s⁻¹</td>
<td>1.12 m·s⁻¹</td>
<td>1.12 m·s⁻¹</td>
<td>1.12 m·s⁻¹</td>
</tr>
</tbody>
</table>

*Note.* AG represents the antigravity treadmill condition and TM represents the regular treadmill condition. The warm up protocol is not shown in the table, but it is implied that individuals warmed up for 2 minutes at 1.12 m·s⁻¹ for both the AG and TM conditions.
Statistical Analyses

Descriptive statistics of mean and standard deviations were calculated for all dependent variables (step length, step rate, contact time, and flight time).

Specific aim #1. The purpose of specific aim #1 was to determine if there was a difference between treadmill condition and speed on step length.

Hypothesis #1. The hypothesis of specific aim #1 was that there would not be a significant difference between treadmill condition and step length; however, there would be a significant difference between treadmill speed and step length.

Statistical analysis. A two-way repeated measures analysis of variance (ANOVA) between treadmill condition and treadmill speed was conducted. Simple main effects of treadmill condition and speed were examined on step length.

Specific aim #2. The purpose of specific aim #2 was to determine if there was a difference between treadmill condition and speed on step rate.

Hypothesis #2. The hypothesis of specific aim #2 was that there would not be a significant difference between treadmill condition and step rate; however, there would be a significant difference between treadmill speed and step rate.

Statistical analysis. A two-way repeated measures analysis of variance (ANOVA) between treadmill condition and treadmill speed was conducted. Simple main effects of treadmill condition and speed were examined on step rate.
Specific aim #3. The purpose of specific aim #3 was to determine if there was a difference between treadmill condition and speed on contact time.

Hypothesis #3. The hypothesis of specific aim #3 was that there would not be a significant difference between treadmill condition and contact time; however, there would be a significant difference between treadmill speed and contact time.

Statistical analysis. A two-way repeated measures analysis of variance (ANOVA) between treadmill condition and treadmill speed was conducted. Simple main effects of treadmill condition and speed were examined on contact time.

Specific aim #4. The purpose of specific aim #4 was to determine if there was a difference between treadmill condition and speed on flight time.

Hypothesis #4. The hypothesis of specific aim #4 was that there would not be a significant difference between treadmill condition and flight time; however, there would be a significant difference between treadmill speed and flight time.

Statistical analysis. A two-way repeated measures analysis of variance (ANOVA) between treadmill condition and treadmill speed was conducted. Simple main effects of treadmill condition and speed were examined on flight time.
CHAPTER 4

RESULTS

The purpose of this study was to examine the interaction effect of different treadmill weighted conditions and three different running velocities on specific kinematic variables while running on the Alter-G treadmill (AG) and on the regular treadmill (TM). Fifteen volunteers participated in this study. Anthropometric measurements of the participants are shown in Table 1. The participants completed two separate days of testing. All individuals ran at four different conditions (100%, 80%, 60%, and 40%) on the antigravity treadmill and once on the regular treadmill. Individuals ran at three different velocities (2.68 m s\(^{-1}\), 3.13 m s\(^{-1}\), and 3.58 m s\(^{-1}\)) during each condition. This chapter includes the primary findings of treadmill weighted condition and speed on step length, step rate, contact time, and flight time.

Step Length

A two-way repeated measures ANOVA was run to determine the effect of treadmill weighted condition and speed on step length. There was a statistically significant interaction between treadmill weighted condition and speed on step length, \(F(8, 112) = 6.660, p < .0005\), partial \(\eta^2 = .322\). Therefore, simple main effects were run. The simple main effects for treadmill condition are presented first.

At 2.68 m s\(^{-1}\), step length was statistically significantly different among the five treadmill conditions, \(F(4, 56) = 47.004, p < .0005\), partial \(\eta^2 = .771\). Post hoc analyses with a Bonferroni adjustment indicated that there were no differences in step length between
the regular treadmill and the 100% condition on the Alter-G (95% CI, [-2.412, 3.709], \( p = 1.000 \)). Also, there were no differences in step length between the regular treadmill and the 80% conditions on the Alter-G (95% CI, [-5.626, 1.025], \( p = .373 \)). There were significant differences in step length between the regular treadmill and the 60% condition on the Alter-G (95% CI, [-11.287, -3.562], \( p < .0005 \), mean difference = 7.425), and also the 40% condition (95% CI, [-17.863, -6.598], \( p < .0005 \), mean difference = 12.230). There were significant differences in step length between the regular treadmill and the 100% and 80% conditions on the Alter-G (95% CI, [-5.107, -.790], \( p < .05 \), mean difference = 2.948). There were significant differences in step length between the 100% and 60% conditions on the Alter-G (95% CI, [-10.505, -5.641], \( p < .0005 \), mean difference = 8.073), and also the 40% condition (95% CI, [-17.576, -8.181], \( p < .0005 \), mean difference = 12.878). The rest of the post hoc analyses indicated that step length gets significantly greater as body weight conditions decreased at 2.68 m/s\(^{-1}\).

At 3.13 m/s\(^{-1}\), step length was statistically significant among the five treadmill conditions, \( F(4, 56) = 44.758, p < .0005 \), partial \( \eta^2 = .762 \). Post hoc analyses with a Bonferroni adjustment indicated that there were no differences in step length between the regular treadmill and the 100% condition on the Alter-G (95% CI, [-3.604, 3.612], \( p = 1.000 \)). There were significant differences in step length between the regular treadmill and the 80% condition on the Alter-G (95% CI, [-8.739, -1.020], \( p < .05 \), mean difference = 4.879), between the regular treadmill and the 60% condition on the Alter-G (95% CI, [-14.303, -3.825], \( p < .0005 \), mean difference = 9.064), and also the 40% condition (95% CI, [-24.328, -9.416], \( p < .0005 \), mean difference = 16.872). There were significant differences in step length between the 100% and the 80% conditions on the Alter-G (95% CI, [-8.321, -
1.445], p < .005, mean difference = 4.883). There were significant differences in step length between the 100% and 60% conditions on the Alter-G (95% CI, [-13.770, -4.366], p < .0005, mean difference = 9.068), and also the 40% condition (95% CI, [-24.308, -9.445], p < .0005, mean difference = 16.876). The rest of the post hoc analyses indicated that step length gets significantly greater as body weight conditions decreased at 3.13 m s$^{-1}$.

At 3.58 m s$^{-1}$, step length was statistically significant among the five treadmill conditions, $F (4, 56) = 48.716, p < .0005$, partial $\eta^2 = .777$. Post hoc analyses with a Bonferroni adjustment indicated that there were no differences in step length between the regular treadmill and the 100% condition on the Alter-G (95% CI, [-4.711, 3.376], p = 1.000). There were significant differences in step length between the regular treadmill and the 80% condition on the Alter-G (95% CI, [-11.130, -2.530], p < .005, mean difference = 6.740), between the regular treadmill and the 60% condition on the Alter-G (95% CI, [-17.939, -5.683], p < .0005, mean difference = 11.811), and also the 40% condition (95% CI, [-27.528, -11.822], p < .0005, mean difference = 19.675). There were significant differences in step length between the 100% and the 80% conditions on the Alter-G (95% CI, [-9.266, -2.779], p < .0005, mean difference = 6.072). There were significant differences in step length between the 100% and 60% conditions on the Alter-G (95% CI, [-16.688, -5.598], p < .0005, mean difference = 11.143), and also the 40% condition (95% CI, [-26.211, -11.803], p < .0005, mean difference = 19.007). The rest of the post hoc analyses indicated that step length gets significantly greater as body weight conditions decreased at 3.58 m s$^{-1}$.

For the regular treadmill weighted condition, step length was statistically significant among the three speeds, $F (2, 28) = 277.381, p < .0005$, partial $\eta^2 = .952$. Post hoc analyses
with a Bonferroni adjustment indicated that step length increased significantly from 2.68 m·s⁻¹ to 3.58 m·s⁻¹ across all five treadmill conditions.

**Figure 4.** Average step lengths by running speed for each treadmill condition.
Step Length

Figure 5. Average step lengths by treadmill condition for each running speed.

Step Rate

A two-way repeated measures ANOVA was run to determine the effect of treadmill weighted condition and speed on step rate. There was not a statistically significant interaction between treadmill weighted condition and speed on step rate, $F(8, 112) = 1.443$, $p = .186$, partial $\eta^2 = .093$. Therefore, the main effects for treadmill weight and speed were run separately.

There was a significant main effect for treadmill weight on step rate, $F = 11.449$, $p < .001$, partial $\eta^2 = .806$. Post hoc analyses with a Bonferroni adjustment indicated that there were no statistically significant differences in step rate between the regular treadmill and the 100% condition on the Alter-G (95% CI, [-.121, .023], $p = .410$). Also, there were no
differences in step rate between the regular treadmill and the 80% conditions on the Alter-G (95% CI, [-.017, .124], p = .235). There were significant differences in step rate between the regular treadmill and the 60% condition on the Alter-G (95% CI, [.071, .274], p < .001, mean difference = .172), and also the 40% condition (95% CI, [.142, .412], p < .0005, mean difference = .277). There were significant differences in step rate between the 100% and 80% conditions on the Alter-G (95% CI, [.027, .178], p < .005, mean difference = .102). There were significant differences in step rate between the 100% and 60% conditions on the Alter-G (95% CI, .116, .326], p < .0005, mean difference = .221), and also the 40% condition (95% CI, [.178, .473], p < .0005, mean difference = .326). The rest of the post hoc analyses indicated that step rate decreased significantly as body weight conditions decreased.

There was a significant main effect for treadmill speed on step rate, $F = 29.682$, $p < .0005$, partial $\eta^2 = .820$. There was a significant linear increase in step rate as speed increased across all conditions, $p < .0005$. 
Figure 6. Average step rate by running speed for each treadmill condition.
Figure 7. Average step rate by treadmill condition for each running speed.

Contact Time

A two-way repeated measures ANOVA was run to determine the effect of treadmill weighted condition and speed on contact time. There was a statistically significant interaction between treadmill weighted condition and speed on step length, $F(8, 112) = 2.263, p < .05$, partial $\eta^2 = .139$. Therefore, simple main effects were run. The simple main effects for treadmill condition are presented first.

At 2.68 m s$^{-1}$, contact time was statistically significantly different among the five treadmill conditions, $F(4, 56) = 27.847, p < .0005$, partial $\eta^2 = .665$. Post hoc analyses with a Bonferroni adjustment indicated that there were no differences in contact time between the regular treadmill and the 100% condition on the Alter-G (95% CI, [-.010, .014],
There were significant differences in contact time between the regular treadmill and the 80% conditions on the Alter-G (95% CI, [.004, .042], $p < .05$, mean difference = .020). There were significant differences in contact time between the regular treadmill and the 60% condition on the Alter-G (95% CI, [.014, .042], $p < .005$, mean difference = .028), and also the 40% condition (95% CI, [.021, .048], $p < .0005$, mean difference = .035). There were significant differences in contact time between the 100% and the 80% conditions on the Alter-G (95% CI, [.005, .029], $p < .05$, mean difference = .017).

At 3.13 m s$^{-1}$, contact time was statistically significant among the five treadmill conditions, $F(4, 56) = 42.760, p < .0005$, partial $\eta^2 = .753$. Post hoc analyses with a Bonferroni adjustment indicated that there were no differences in step length between the regular treadmill and the 100% condition on the Alter-G (95% CI, [-.005, .011], $p = 1.000$). There were significant differences in contact time between the regular treadmill and the 80% condition on the Alter-G (95% CI, [.004, .036], $p < .05$, mean difference = .020), between the regular treadmill and the 60% condition on the Alter-G (95% CI, [.014, .042], $p < .0005$, mean difference = .028), and also the 40% condition (95% CI, [.021, .048], $p < .0005$, mean difference = .035). There were significant differences in contact time between the 100% and the 80% conditions on the Alter-G (95% CI, [.005, .029], $p < .05$, mean difference = .017).

There were significant differences in contact time between the regular treadmill and the 80% conditions on the Alter-G (95% CI, [.000, .042], $p < .05$, mean difference = .021). There were significant differences in contact time between the regular treadmill and the 60% condition on the Alter-G (95% CI, [.009, .050], $p < .005$, mean difference = .029), and also the 40% condition (95% CI, [.024, .056], $p < .0005$, mean difference = .040). There were significant differences in contact time between the 100% and 80% conditions on the Alter-G (95% CI, [.004, -.035], $p < .05$, mean difference = .019). There were significant differences in contact time between the 100% and 60% conditions on the Alter-G (95% CI, [.012, .043], $p < .0005$, mean difference = .028), and also the 40% condition (95% CI, [.021, .055], $p < .0005$, mean difference = .038). The rest of the post hoc analyses indicated that contact time decreased significantly as body weight conditions decreased at 2.68 m s$^{-1}$.
condition (95% CI, [.020, .043], \( p < .0005 \), mean difference = .031). The rest of the post hoc analyses indicated that contact time decreased significantly as body weight conditions decreased at 3.13 m s\(^{-1}\).

At 3.58 m s\(^{-1}\), contact time was statistically significant among the five treadmill conditions, \( F(4, 56) = 52.640, \ p < .0005 \), partial \( \eta^2 = .787 \). Post hoc analyses with a Bonferroni adjustment indicated that there were no statistically significant differences in contact time between the regular treadmill and the 100% condition on the Alter-G (95% CI, [-.002, .013], \( p = .334 \)). There were significant differences in contact time between the regular treadmill and the 80% condition on the Alter-G (95% CI, [.005, .026], \( p < .005 \), mean difference = .015), between the regular treadmill and the 60% condition on the Alter-G (95% CI, [.011, .032], \( p < .0005 \), mean difference = .022), and also the 40% condition (95% CI, [.026, .040], \( p < .0005 \), mean difference = .033). There were significant differences in contact time between the 100% and the 80% conditions on the Alter-G (95% CI, [.000016, .020], \( p < .05 \), mean difference = .010). There were significant differences in contact time between the 100% and 60% conditions on the Alter-G (95% CI, [.009, .023], \( p < .0005 \), mean difference = .016), and also the 40% condition (95% CI, [.020, .035], \( p < .0005 \), mean difference = .028). The rest of the post hoc analyses indicated that contact time decreased significantly as body weight conditions decreased at 3.58 m s\(^{-1}\).

For the regular treadmill weighted condition, contact time was statistically significant among the three speeds, \( F(2, 28) = 163.571, \ p < .0005 \), partial \( \eta^2 = .921 \). Post hoc analyses with a Bonferroni adjustment indicated that contact time decreased significantly from 6-mph to 8-mph across all five treadmill-weighted conditions.
Figure 8. Average contact time by running speed for each treadmill condition.
Figure 9. Average contact time by treadmill condition for each running speed.

Flight Time

A two-way repeated measures ANOVA was run to determine the effect of treadmill weighted condition and speed on flight time. There was not a statistically significant interaction between treadmill weighted condition and speed on flight time, $F(8, 112) = 1.223, p = .292$, partial $\eta^2 = .080$. Therefore, the main effects for treadmill weight and speed were run separately.

There was a significant main effect for treadmill weight on flight time, $F = 42.180, p < .0005$, partial $\eta^2 = .939$. Post hoc analyses with a Bonferroni adjustment indicated that there were no differences in flight time between the regular treadmill and the 100% condition on the Alter-G (95% CI, [-.006, .011], $p = 1.000$). There were significant
differences in flight time between the regular treadmill and the 80% conditions on the Alter-G (95% CI, [-.041, -.010], \(p < .001\)). There were significant differences in flight time between the regular treadmill and the 60% condition on the Alter-G (95% CI, [-.064, -.035], \(p < .0005\), mean difference = .050), and also the 40% condition (95% CI, [-.094, -.058], \(p < .0005\), mean difference = .076). The rest of the post hoc analyses indicated that flight time increased significantly as body weight conditions decreased.

There was a significant main effect for treadmill speed on flight time, \(F = 79.243, p < .0005\), \(\eta^2 = .924\). There was a significant linear increase in flight time as speed increased across all conditions, \(p < .0005\).

![Flight Time](image)

**Figure 10.** Average flight time by running speed for each treadmill condition.
Figure 11. Average flight time by treadmill condition for each running speed.
CHAPTER 5
DISCUSSION AND CONCLUSIONS

The Alter-G lower body positive pressure treadmill, also known as the antigravity treadmill, provides a unique means of exercising for individuals, especially to those who are obese, experiencing lower extremity injuries, or rehabilitating from other conditions. However, there has been limited research conducted on how gait mechanics are affected while running on this machine. The purpose of this study was to examine the interaction effect of different treadmill weighted conditions and three different running velocities on specific kinematic variables while running on the Alter-G treadmill (AG) and on the regular treadmill (TM). Step length, step rate, contact time, and flight time were measured in this study. The results of this analysis could contribute to rehabilitation and training protocols for individuals by measuring running kinematics at multiple body weight percentages and velocities on the Alter-G treadmill.

The four kinematic variables were significantly different among the treadmill-weighted conditions. However, there were no significant differences in the running kinematics between the regular treadmill and the 100% condition on the Alter-G treadmill. The results also indicated that the four kinematic variables were significantly different between all three running velocities.

Therefore, the first hypothesis can be rejected and the null hypothesis can be accepted; the findings pertaining to the first hypothesis indicated that the four running kinematic variables are significantly different between the treadmill-weighted conditions (Alter-G treadmill 100%, 80%, 60%, and 40%). There was a significant linear increase in step length as body weight conditions decreased at all three speeds (Figure 4). There
was a significant decrease in step rate as body weight conditions decreased for all three speeds (Figure 6). Contact time also decreased significantly as body rates were reduced (Figure 8), and flight time increased significantly as body weight conditions decreased (Figure 10).

The second hypothesis can be accepted; the findings pertaining to the second hypothesis showed that the four running kinematic variables would not be significantly different between the regular treadmill and the 100% condition on the Alter-G treadmill.

We can also accept the third hypothesis; the results pertaining to the third hypothesis indicated that the four running kinematic variables would be significantly different between velocities (2.68 m\,s^{-1}, 3.13 m\,s^{-1}, and 3.58 m\,s^{-1}). Step length, step rate, and flight time increased significantly as speed increased (Figure 5, Figure 7, and Figure 11). However, contact time decreased significantly as speed increased (Figure 9).

The results of this study are applicable to findings of previous literature. Riley et al. (2008) concluded that parameters measured during treadmill running are comparable, but not directly equivalent to parameters measured during overground running. The authors determined that treadmill and overground running gait patterns are similar with slight differences in kinematic and kinetic variables. In the current study, there were no significant differences in the four running kinematic variables between the regular treadmill and the 100% condition on the Alter-G treadmill. Therefore, gait patterns at the 100% condition on the Alter-G are probably similar to overground running parameters due to the findings of Riley et al. (2008), but further research is needed.

The results of the kinematic variables across varying Alter-G conditions confirmed similar findings by Raffalt el al. (2013). The findings demonstrated that as body weight
percentage was reduced, step frequency and contact time decreased; also, as body weight percentage was reduced, step length and flight time increased (Raffalt et al., 2013). These same trends were found in the current study, which are demonstrated in Figures 4, 6, 8, and 10. However, Raffalt et al. (2013) tested participants at different body weight conditions on the Alter-G treadmill (100%, 75%, 50%, and 25%), as well as different speeds (steady state running at 2.78 m s\(^{-1}\), 3.89 m s\(^{-1}\) and 5.00 m s\(^{-1}\), and high speed running at 5.56 m s\(^{-1}\) and 6.11 m s\(^{-1}\)). Additionally, Raffalt et al. (2013) found that step rate and contact time decreased with increasing speeds, and step length and flight time increased with increasing speeds. Similar trends were also found in the current study and are shown in Figures 5, 9, and 11. However, the results of step rate were different; step rate increased with increasing speeds (Figure 7). The results in step rate could be different than Raffalt et al. (2013) because the authors measured longer durations of running and randomized the order of body weight conditions compared to the protocol of the current study.

Patil et al. (2013) confirmed that step length increased with increasing speeds. These authors examined the same body weight conditions as the authors of Raffalt et al. (2013); however, Patil et al. (2013) measured walking on the Alter-G treadmill instead of running. Therefore, no significant differences were found in body weight reduction on step length. Cutuk et al. (2006) concluded that stride length increased significantly during running compared to walking when body weight conditions were decreased.
Conclusion

There has been limited research conducted on the biomechanics of running on the Alter-G treadmill at the conditions (100%, 80%, 60%, and 40%) and speeds (2.68 m s\(^{-1}\), 3.13 m s\(^{-1}\), and 3.58 m s\(^{-1}\)) that were used in this study. Theoretically, this study extended the research by examining kinematic variables at these different speeds and body weights on the Alter-G treadmill. Results demonstrated that faster speeds could be simulated with running at slower speeds at decreased body weights. For example, running at 3.58 m s\(^{-1}\) during the 60% condition output similar contact times when running at 3.13 m s\(^{-1}\) during the 40% condition (Figure 8). Another example demonstrated in Figure 10, running at 3.13 m s\(^{-1}\) at the 60% condition output similar flight times when running at 2.68 m s\(^{-1}\) during the 40% condition. In conclusion, practitioners can imply the results from this study when determining exercise protocols for rehabilitation patients, as well as training protocols for athletes. This could benefit physicians, therapists, and coaches who may be interested in using the Alter-G treadmill for treatment or exercise.

There were some limitations to this study. Measurements of contact time and flight, thus step rate, may have been influenced by the exact measurement of touchdown and takeoff. There was minor difficulty identifying the exact frame of touchdown and takeoff, primarily on the Alter-G treadmill. This may have introduced an error by 1-2 frames (.003-.007s). The reasons contributing to this error could be due to lighting, shoe type and color, and the vinyl window of the Alter-G. Also, the difficulty in identifying touchdown occurred more with forefoot strikers. Some other limitations were inexperience running at the faster speeds for some participants, and unfamiliarity with
running on the Alter-G treadmill. However, the results indicated similar trends to previous research.

Future research should continue to examine running kinematics on the Alter-G treadmill. Different speeds, body weight percentages, and longer durations should be investigated to determine how gait is affected. There should also be research conducted with experienced runners to assist with training procedures for individuals looking to use this treadmill during exercise. Future studies could also investigate other rehabilitation populations. Future research on kinematic variables on the Alter-G treadmill may provide useful information to practitioners about rehabilitation and training protocols.
References


Appendix A - Descriptive Statistics of the Dependent Variables

Table 3

*Descriptive Statistics of Step Length (n=15)*

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<th>Condition</th>
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Table 4

*Descriptive Statistics of Step Rate (n=15)*

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Table 5

*Descriptive Statistics of Contact Time (n=15)*

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<th>Std. Deviation (s)</th>
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Table 6

*Descriptive Statistics of Flight Time (n=15)*

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</table>
Appendix B- Informed Consent

Document of Informed Consent
Department of Kinesiology
State University College at Cortland

TITLE: Do running kinematics change on the Alter-G treadmill?

STUDENT INVESTIGATOR: Brittany LaVaute, (315)-289-8842

FACULTY SUPERVISOR: Peter McGinnis, PhD., (607)-753-4909

PURPOSE: The purpose of this study is to examine the interaction effect of different treadmill weighted conditions and three different running velocities on the kinematic variables of step length, step rate, contact time, and flight time on the Alter-G treadmill (AG) and on the regular treadmill (TM).

PROCEDURES: You will run on two different treadmills (Alter-G and regular treadmill) at three different speeds. You will run on each treadmill on two different days. Each testing day will take approximately 30 minutes to complete. You will complete four conditions on the Alter-G treadmill. You will run for 45-second intervals and each run interval will be interspersed with a 30-second walk. Video cameras will be set up to collect the kinematic variables of step length, step rate, contact time, and flight time. Video cameras will only record the lower extremities from the waist down during the running intervals. These video records will be used later to analyze the kinematic variables through the Tracker video analysis program.

RISKS: The proper precautions will be taken to ensure that the testing area, as well as all of the equipment being used, is safe for all participants involved in the study. The possibility of injury in this study is no more than minimal risk. The risks involve confidentiality of the video records and running on the treadmill. Your name will not be associated with the video records and instead, you will be assigned a random number to protect your confidentiality. You will be given instructions and familiarized with the Alter-G treadmill prior to data collection to minimize any possible injuries.

BENEFITS: The results of this study may not benefit you personally. However, the results can help demonstrate the benefits of using the Alter-G antigravity treadmill as another method for rehabilitation and training purposes and contribute to developing effective protocols for individuals.

CONFIDENTIALITY: All of the data from the experiment will be stored in a locked cabinet, and the data on the computer will be stored anonymously with your identity protected.

FREEDOM OF CONSENT: Participation in this study is completely voluntary, and you may withdraw from the project at any time, for any reason, without penalty.

The student responsible for this research project is Brittany LaVaute, who will be working in conjunction with the faculty members of the SUNY Cortland Kinesiology Department. For questions concerning the rights of human subjects, please contact Amy Henderson-Harr, Human Subjects Committee at SUNY Cortland, (607)753-2511.

I have read and understand the activities required for my involvement in this project, and I consent to participate.

Name: __________________________ Telephone#: __________________________

Signature: __________________________ Date: _____________
Appendix C- Informed Consent Approval Letter

MEMORANDUM

To: Brittany LaVauta
    Peter McGennis

From: Jena Curtis, Chair
      Institutional Review Board

Date: 1/15/2016

RE: Institutional Review Board Approval

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

Title of the study: Do running kinematics change on the Alter-G treadmill?

Level of review: Expedited

Protocol number: 1562

Project start date: Upon IRB approval

Approval expiration date*: 1/14/2016

* Note: Please include the protocol expiration date to the bottom of your consent form and recruitment materials.

For more information about continuation policies and procedures, visit www.cortland.edu/irb/Applications/continuations.html

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

- obtaining and documenting informed consent from the participants and/or from a legally authorized representative prior to the individuals’ participation in the research, unless these requirements have been waived by the IRB;
- obtaining prior approval from the IRB for any modifications of (or additions to) the previously approved research; this includes modifications to advertisements and other recruitment materials, changes to the informed consent or child assent, the study design and procedures, addition of research staff or student assistants, etc. (except those alterations necessary to eliminate apparent immediate hazards to subjects, which are then to be reported by email to irb@cortland.edu within three days);
- providing to the IRB prompt reports of any unanticipated problems involving risks to subjects or others;
- notifying the IRB of continued research under the approved protocol to keep the records active; and,
- maintaining records as required by the HHS regulations and NYS State law, for at least three years after completion of the study.
In the event that questions or concerns arise about research at SUNY Cortland, please contact the IRB by email irb@cortland.edu or by telephone at (607) 753-2511. You may also contact a member of the IRB who possesses expertise in your discipline or methodology. visit http://www.cortland.edu/irb/members.html to obtain a current list of IRB members.

Sincerely,

Jena Curtis, Chair
Institutional Review Board
SUNY Cortland
Appendix D- PAR-Q

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

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

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

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

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?</td>
<td></td>
</tr>
<tr>
<td>2. Do you feel pain in your chest when you do physical activity?</td>
<td></td>
</tr>
<tr>
<td>3. In the past month, have you had chest pain when you were not doing physical activity?</td>
<td></td>
</tr>
<tr>
<td>4. Do you lose your balance because of dizziness or do you ever lose consciousness?</td>
<td></td>
</tr>
<tr>
<td>5. Do you have a bone or joint problem (for example, back, knees or hip) that could be made worse by a change in your physical activity?</td>
<td></td>
</tr>
<tr>
<td>6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?</td>
<td></td>
</tr>
<tr>
<td>7. Do you know of any other reason why you should not do physical activity?</td>
<td></td>
</tr>
</tbody>
</table>

If you answered YES to one or more questions

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

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

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

- start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live physically. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

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

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

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

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

_NAME_

SIGNATURE

_DATE_

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

_NAme_

_DATE_

_WHERE_

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

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