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The effects of Quadmill training on balance: An intervention study

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The Effects of Quadmill^{TM} Training on Balance: An Intervention Study

by

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Abstract

The purpose of this study was to observe and compare the effects of two separate training interventions using the Quadmill™ to a control group on balance in college-aged individuals. It was hypothesized that both experimental groups (I_1 and I_2) would experience improvements in balance over the intervention whereas the control group would remain at baseline. It was secondarily hypothesized that I_2 would experience greater improvements than I_1 in balance due to the nature of the exercise protocol. Data was collected using three systems; Balance Tracking Systems, Star Excursion Balance Test, and the Biodex Balance system. A two-way mixed methods ANOVA revealed no significant group by time interaction or group main effects for any dependent variable. Further analysis showed a significant main effect of time for nine dependent variables with a statistical significance for each of $p < .05$. It was concluded that there was no difference between the two Quadmill™ training methods (I_1, I_2) on improving balance. It was also concluded that there was no difference between I_1 and I_2 and the control group C_1.

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Chapter 1

Introduction

The ability to function independently is an important aspect of daily living. Without the ability to be independent, normal daily activities and quality of life are greatly reduced. One component of independence is free movement. Movement without constraints allows individuals to be productive members of society and function in the way our society demands today. The human body is a complicated system and often times the slightest disruption can cause irregularities throughout. In terms of independence and movement, one sensitive sub-component that when disrupted can cause major complications is balance. Balance is the ability to keep a vertical body position over a base of support (Winter, 1995). Balance is comprised of three systems; Visual, Vestibular, and the Somatic-Sensory. Each system works synchronously to coordinate movement. Issues with any of these systems will have direct effect on balance, which inherently effects movement and independence. Keeping these systems intact is most important to vulnerable populations with compromised health statuses. A result of a balance dysfunction can be a fall. A fall can be defined a loss of body control resulting in that individual coming to rest on the ground (Berg, 1992). Fatal and injurious falls plague the elderly and put an enormous stress on the health care system (Stevens, 2006). Regular exercise can help to improve quality of life; however, a feasible and effective program that suits specific needs of a population may be more beneficial.

Exercise can help to improve quality of life through improving functioning in the muscular, nervous, and cardiovascular systems (Gill, 2013). Improvements in these systems can lead to improvements in associate other components such as balance. Studies conducted by Hall (1999), Nick (2016) and Johnson (2007) have shown that unconventional exercise-based programs are effective and safe for elderly populations; however, in many cases, such programs can be overly time-consuming or challenging. For example, a strength-training program may involve movements that are not necessarily fitted for every individual in this group and may require individuals to work for 45 minutes to an hour. A yoga session may require individuals to push the limits of their bodies into positions that may be harmful and can take up to an hour of training per session. Modifications can be made to lessen the difficulty of the tasks, however the effort needed may be overly taxing. The time commitment and difficulty of the tasks may prove too challenging for these individuals to accomplish. The Quadmill™ is a low-impact and time-efficient method for training the lower body. On average, a training session may take 10-15 minutes to complete, just a fraction of the amount of time compared to a more conventional strength training or yoga session. This piece of equipment may be an efficient way to exercise for various populations in that it forces individuals to perform a dynamic movement while taxing lower extremity muscles in a short period of time. The Quadmill™ offers a safe, non-committal way for an individual to exercise intensely.

Statement of the Problem

The inability to control body position during movement can be an issue for an individual. A fall is characterized as “unexpected events that result with an individual unintentionally coming to rest on the ground, floor, or lower level” (Lamb, 2005). It has been shown that daily moderate-to-vigorous physical activity is a primary fall prevention strategy in elderly women (Heesch, 2008), but participation only in daily physical activity may not be the best prevention strategy for every individual.

With very little research implementing the use of the Quadmill™, appendix A, an investigation into its effects on balance may worthwhile. The Quadmill^{TM} helps to build strength in the body's lower extremities muscles through cyclical training. Exploring the effects of a training intervention using the Quadmill^{TM} on college-age adults, ages 18-22 years old, may shed light on effects of the training on balance.

Purpose of the Study

The purpose of this study was to compare the effects of two training interventions using the Quadmill^{TM} to a control group on balance in healthy college age adults.

Hypothesis

It was hypothesized that both training groups would improve balance from pre-test to mid to post-test and the control group would show no improvements. A secondary hypothesis was that the 4-way Quadmill^{TM} training group would experience a greater improvement in balance after six weeks of training than the 1-way Quadmill^{TM} group.

Delimitations

The participants were college-aged adults 18-22 years old. Participants were either male or female without an injury or complication to the brain (i.e. concussion) or lower body (joint, tendon, or muscular) within the past 6 months. Two intervention groups, I_1 and $I_{2,}$ completed twelve training sessions over six weeks. I_1 completed four 30-second bouts at a 38-rpm setting facing forward on the Quadmill™. I_2 completed four 30-second bouts at a 38-rpm setting facing forward, to the right, backwards, and to the left each training day. C_1 completed just the three balance testing protocols. The control group went about their normal daily lifestyle for the duration of the intervention, with no restrictions on activity levels. The Quadmill^{TM} was used as the intervention equipment because of its unique design and function, availability, and lack of research of its impact on balance. The Balance Tracking

Systems balance plate and software, Explore Balance, Biodex Balance SD, and the Star Excursion Balance Test were used as the testing measures evaluating numerous variables related to balance.

Limitations

The sample comprised of healthy, college-aged individuals and thus results can only be generalized to healthy, college-aged individuals. Each participant completed their training on different days of the week at different times each day to fit the schedules of both the participants and researchers. Footwear was not controlled for. Although sneakers were required, the exact make and model varied for each participant. Diet and daily activity was not controlled for, and with that, fluctuations in weight and training status may have occurred. Some individuals consumed caffeine during the post-test, which may have affected the results. Some individuals were admittedly not feeling well as a result of alcohol consumption from the previous night. Numerous individuals took part in their own strength training programs outside of the study. Many of these individuals experienced muscles soreness from this outside activity during both training and testing sessions. This added training may have impacted the results of this study. Participants did not have a practice session on the Quadmill™ prior to the start of the intervention but did have an orientation session where the proper techniques while exercising were demonstrated. Although it was assumed that participants lead similar lifestyles and were of similar anthropometric make-up, differences in baseline training levels might have occurred.

Assumptions

It was assumed that each individual was honest and forthcoming when completing pre-testing questionnaires and reported true ratings of perceived exertion during training. It was assumed that each participant put forth maximal effort during all training sessions and testing sessions. It was assumed that each participant lived a healthy lifestyle, including getting proper sleep, maintaining a balanced diet, and adhering to a moderate level of activity leading up to and during the study. Based on the population, it was assumed that all participants are of similar anthropometric make up.

Definition of Terms

- *Balance*- The ability to maintain a line of gravity, vertical to the center of gravity, within a base of support (McGinnis, 2013)
- *Center of gravity*- The average location of an object's average weight (McGinnis, 2013).
- *Center of pressure*- The point where the total sum of a pressure field acts on a body causing force to act through that point (McGinnis, 2013)
- *Detrained*- A state/period of time with little to no involvement of vigorous activity (both cardiovascularly and muscularly) (Baechle, 2008).
- *Eccentric training*- Training where the muscle is working most during the lengthening phase of a movement (Baechle, 2008).
- *Motor control*- The process in which animals and humans use their brain and cognition to coordinate their limbs and muscles in order to perform a motor skill (Coker, 2013)
- *Motor skill*- A function involving the use of muscles to perform voluntary, goal-oriented actions (Coker, 2013).
- *Postural sway*- Horizontal movement in relation to one's center of gravity (McGinnis, 2013)

- *Proprioception*- one's awareness of their body's position in space (McGinnis, 2013)
- *Quadmill^{TM}*- Motorized piece of exercise equipment with the primary intention of training the lower body eccentrically.
- *Static balance*- Occurs when an object remains stationary about its axis of rotation.
- *Vestibular system*- Region of inner ear with three semicircular canals coupled with the visual system to keep focus while the head is in motion.

Significance of the Study

This study's aim was to explore the potential benefits of an alternative training method on balance. Results from a six-week training intervention indicated that training on the Quadmill^{TM} improved acute aspects balance. Due to the nature of the exercise, adherence to such an exercise regime was high in a healthy college population as time commitment and complexity of movement were low to minimal. With these observations, future research involving the Quadmill^{TM} is recommended.

Chapter 2

Review of Literature

Nearly four million years ago humans began walking upright, making them unique and highly adaptable to different habitats (Lewin, 2004). Walking upright allowed early humans to more efficiently acquire the necessities for survival. The ability to move to perform activities of daily living, which are necessary for survival, is often overlooked, especially in current times where transportation and resource availability are abundantly available. Most do not consider the complications of immobility, which could lead to impairments or disability until they have experienced it directly or indirectly. The threat of immobility to one's independence is considerable and often overlooked.

Anatomy of Balance

The ability to stand upright and move about is the product of different systems in the body working together to produce a desired movement. The nervous system plays an integral role in movement by connecting the brain and spinal cord to the nerves and relaying information to appropriate systems. The nervous system is organized into the central nervous system, containing the brain and spinal cord, and the peripheral nervous system, which is comprised of all the surrounding nerve tissue located outside of the skull and vertebral column (McGinnis, 2013). The fundamental unit of the nervous system is the neuron. The three types of neurons are sensory, motor, and interneurons. These cells function by receiving a stimulus and sending signals back to or away from the central nervous system. Communication between nerve cells is one way in which the body functions and allows humans to stand upright in a neuromuscular sense. Balance is described as the ability to maintain a vertical line on a base of support and is a crucial component of standing. The ability to stay upright for prolonged periods of time is most important when speaking of movement. An individual's ability to stand upright is the product of multiple systems in the body working together and is termed equilibrioception. The main components of equilibrioception are proprioceptors, the vestibular system, and the visual system.

Proprioception is the continuous flow of sensory information regarding movement and body position that is received from receptors located in the muscles, tendons, joints, and inner ear (Coker, 2013). Proprioceptors located in muscles are called muscle spindles and they act to detect the stretch of a muscle relative to its change in length, also called the stretch reflex. Receptors located in tendons are called Golgi tendon organs, and they detect changes in muscle tension, also referred to as tendon reflex (Schmidt, 2011). Each of these receptors sense changes in the muscle and relay information back to the central nervous system in order to monitor the musculoskeletal system and in turn have a direct function in movement. The vestibular system is located in the inner ear and its components directly affect balance. The proprioceptors in this system are the semicircular canals, the utricle and the saccule (McGinnis, 2013). Each receptor is a bony, hollowed structure that contains fluid call endolymph. The fluid moves relative to head positioning, and bends tiny sensory hairs within the structures, which gives feedback on changes in position and acceleration of the head (McGinnis, 2013). The visual system is vital to movement and balance. The visual system is comprised of the eye and all its components; the sensory receptors in the eye are called photoreceptors, which function by converting light entering through the eye into nerve impulses to be relayed to the associated systems for processing.

Exercise and Balance

Exercise has been shown in multiple studies to improve balance outcome measures over time in healthy populations. Balance training moreover has shown significant increases in balance outcomes in healthy populations. Daneshjoo (2012) investigated the effect of comprehensive warm up programs on proprioception, and static and dynamic balance in male soccer players. This study investigated the effects of FIFA 11+ and HarmoKnee on proprioception and on the static and dynamic balance of pro soccer players. Thirty-six U-21 soccer players were divided into three groups. Proprioception was measured bilaterally at 30, 45, and 60 degrees knee flexion measured using the Biodex dynamometer. Static and dynamic balance was assessed with the stork stance test and star excursion balance test. Results showed proprioception error in the dominant leg decreased more in the FIFA 11+ group at 45 and 60 degrees compared to the HarmoKnee. Significant increases in static balance in the Star excursion balance test in both groups were also found. Daneshjoo (2012) concluded that both programs proved to be useful warm up protocols for improving proprioception at 45 and 60 degrees of knee flexion as well as in static and dynamic balance.

A study conducted by Yaggie (2006) investigated the effects of balance training on selected skills. A 4-week balance training intervention on specific functional tasks was assessed in a sample of thirty-six participants who were placed into control and experimental groups. The experimental group used a BOSU ball for training. Postural limits, displacement and sway, were assessed during a pre-test, post-test and two weeks post training. Results showed that after the post-test there were significant differences in time on ball, shuttle run, total sway and displacement. At two weeks post training, participants' total sway and time on ball remained constant and no other measures were retained. Balance training improved performance of selected sport related activities and postural control measures.

A study conducted by Iacono (2016) examined core stability training on lower limb balance ability. Twenty soccer players were divided into two groups, core training or control. The effects of the training were assessed using isokinetic tests and single leg countermovement jumps. Significant improvement in knee extensors' peak torque, knee flexor peak torque, and peak torque ratios were found and thus the authors concluded that core training does improve balance strength in the lower body.

Alternate Training Methods

Conventional balance training exercises and programs have shown to positively impact balance parameters. However, many of these protocols involve training that may not be suitable to all populations. Alternative exercise methods have also been shown to have positively impact balance. These methods include vibration training, virtual reality, Tai Chi/Pilates/Yoga, video gaming/exergaming, perturbations, sensorimotor, biofeedback, and unstable surface training.

A study conducted by Johnson et al. (2007) examined the effects of Pilates-based exercise on dynamic balance in healthy adults over the course of 10 Pilate's sessions. After the 10 sessions significant changes in dynamic balance were found for the experimental group, but not the control group. A similar study conducted by Hall et al. (1999) showed similar results after a Pilates-based exercise program in older adults.

Nick et al. (2016) observed the effects of yoga practice on balance. Older adults (*n* = 40; men = 17, women = 23) participated in two yoga sessions per week for eight weeks. The modified falls and efficacy scale and Berg balance test were used to assess balance and the fear of falling at pre- and post-intervention time points. Significant differences were observed for both measures in the intervention group and no differences were found in the control group.

These are just a small example of how alternate training methods can induce similar effects on balance on more conventional methods.

Quadmill^{TM}

The Quadmill^{TM} is a piece of cardiovascular training equipment manufactured by reACT training systems. This piece of equipment is unique in that it cyclically works the lower body through eccentric training. The machine is built similarly to other popular cardiovascular machines. However, while on the Quadmill^{TM}, the individual stands on a flat, rotating platform that moves both vertically and horizontally in a circular motion. It was designed to allow for low-impact, high-intensity training with exercise bouts lasting short periods of time. The individual absorbs the motion with their lower body so as to only move from the waist down, keeping the upper body in a fixed position. The motion mirrors pedaling backwards on a bicycle with both legs at the same time. More specifically, its observed benefits include rapid increases in muscle mass and power output, improved balance, coordination, and muscle shock absorption.

Balance Tracking Sytem

The Balance Tracking Systems balance board functions as a force plate. This easy to use and portable piece of technology functions as a force plate. After following cues by the researcher to stand on the platform, an individual stands on the platform with their hands at their side for an allotted time, in this case it is 20 seconds. The machine's software captures information on the individual standing on the platform and, depending on what factors are being analyzed, displays them as such.

Star Excursion Balance Test

The star excursion balance test detects functional performance deficits associated with lower extremity pathology in healthy or impaired populations (Reiman, 2009). This test assesses functional reach by challenging balance and postural control through a dynamic test. The test incorporates reaching in eight directions with one foot planted on a central point and the opposite foot acting as the reach leg. The test is measured in distance reached with the reach leg and a higher reach indicates a longer reach and better balance. The test includes reach measurements in eight directions, however, it has been found that reach in the posterior-medial direction is the most representative direction of overall score on the test and that the medial and anterior medial directions may be used in the clinical evaluation of those with and without chronic ankle instability rather than using all eight directions (Hertel, 2015).

Biodex Balance System

The Biodex Medical System tests both static and dynamic balance. It has numerous functions including fall screening tests and conditioning programs. This system quantifies the ability to maintain dynamic bilateral and unilateral postural stability on a static or unstable surface. The Biodex system is a diverse system with both balance tests and training modes built into the software. It is a widely applicable system as well. It can be used to assess potential head injuries (i.e. concussion testing), balance disparities/dysfunctions, and it has several different training modules for balance improvement and joint mobility in a rehabilitative approach.

The Biodex system has been used in many studies concerning balance. It has been used as both a training tool and assessment tool. Gioftsidou et al. (2011) investigated the effects of a soccer training session on the balance ability of young soccer athletes. Participants' (*n* = 26) balance was measured by the Biodex systems pre- and post-training sessions. No significant differences in balance ability were observed from pre to post testing. Similarly, Gusi et al. (2012) used the Biodex as a training tool. This study involved participants who lived in a nursing home and had a fear of falling. Participants (*n* = 40) completed a 12-week balance training protocol on the balancing/rebalancing module in the Biodex. The outcome measures were fear of falling (Falls Efficacy Scale International questionnaire), dynamic balance (Fall Risk Test) and isometric strength (torque of knee flexor and extensor isometric strength measured with an isokinetic dynamometer). Outcome measures were taken before and after the training program. Compared to the control group, the experimental group experienced significant changes in all outcome measures.

Chapter 3

Methods

There are numerous training modalities shown to improve balance, however, not all types of modalities are not designed to fit every individual. The Quadmill^{TM} by reACT systems is a piece of lower extremity exercise equipment that may accommodate certain needs. Exercising on the Quadmill^{TM} is a safe and effective exercise modality that trains lower extremity muscles. Little research has been conducted on training on this machine and evaluating the effects of training on balance may be helpful for those in need of a different exercise modality.

Study Design

This study observed the effects of a six-week training intervention exercising on the Quadmill^{TM} on balance in healthy college-age individuals. Independent variables included group and time. Dependent variables are presented in Table 1.

Table 1.
Dependent Variables from Associated System

Variable	BTS	SEBT	BD
Total Sway EO	X		
Velocity EO	X		
Distance EO	X		
Frequency EO	X		
RMS ML EO	X		
RMS AP EO	X		
95 % CI EO	X		
EXC ML EO	X		
EXC AP EO	X		
Total Sway ES	X		
Velocity ES	X		
Distance ES	X		
Frequency ES	X		
RMS ML ES	X		
RMS AP ES	X		
95 % CI ES	X		
EXC ML ES	X		
EXC AP ES	X		
RFR ANT		X	
RFR PL		X	
RFR PM		X	
LFR ANT		X	
LFR PL		X	
LFR PM		X	
BD OV			X
BD TM			X

Note: BTS = Balance Tracking System, EO = eyes open, RMS = root mean square, ML = medial lateral, AP = anterior posterior, EXC = excursion, CI = confidence interval, ES = eyes shut, SEBT = star excursion balance test, RFR = right foot reach, ANT = anterior, PL = posterior lateral, PM = posterior medial, LFR= left foot reach, BD = biodex, OV = overall score, TM = time.

Participants

College-aged students ranging from 18-22 years old were recruited through the Kinesiology Department at SUNY Cortland. Individuals who were interested were instructed to sign-up with their names and email addresses after a brief five-minute presentation was given by the head researcher. A total of 43 individuals signed up after three separate presentations. This exceeded the number of 30 individuals necessary to produce a moderate effect size estimated by a power analysis that was conducted using G*power software version 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009). These individuals were then informed via email that they had been selected for the study and to respond with a schedule of their availability. After being contacted through email, four individuals responded and informed the researchers that they were not going to participate. Of the 13 individuals who were not initially selected, four were then randomly selected and informed via email that they had been selected after the second round of recruitment. These individuals provided the researchers with schedules of their availabilities. Informed consent forms were distributed to each subject at the time of the pre-test and completed prior to the start of the testing.

Participants were excluded from the study if they had experienced any head or lower body joint injuries within six months of the start of the intervention. Participation in the study was voluntary and participants had right to drop out of the study at any time. During the intervention, one individual dropped out due to an illness and another was injured prior to completing the post-test. The first individual responses were completely excluded from the study and the second individual's pre-test and mid-test data was used in the statistical analysis.

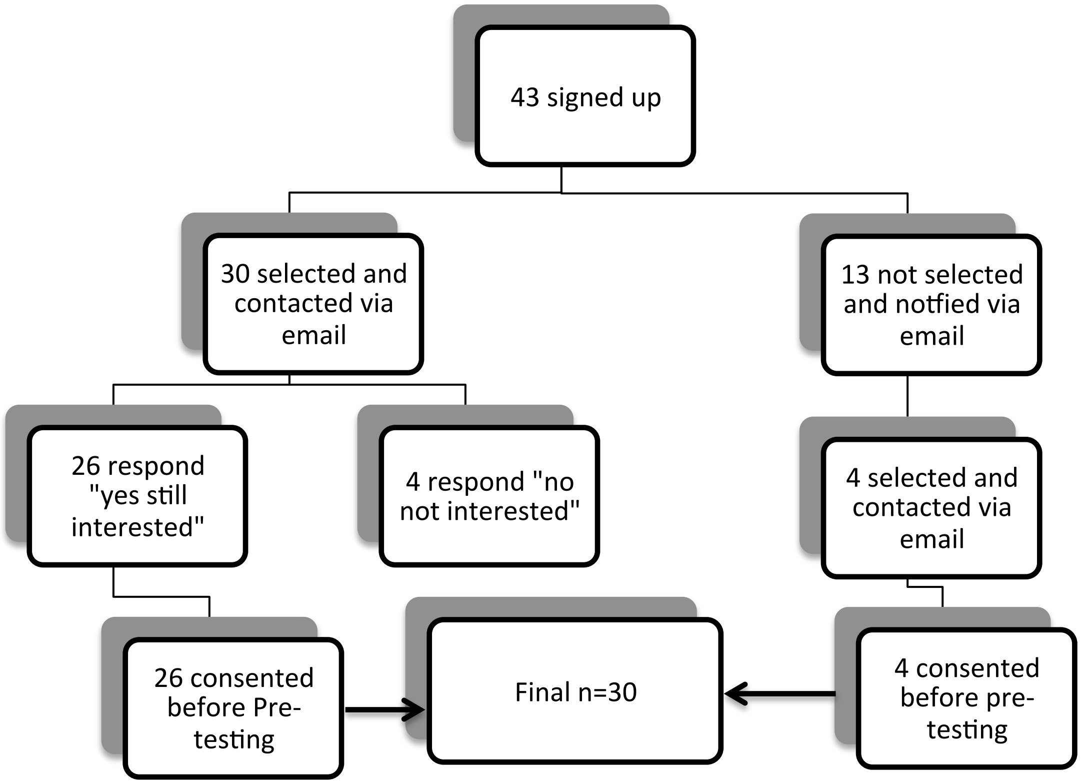


Figure 1. Recruitment Breakdown

Instruments

Balance Tracking System (San Diego, CA). The Balance Tracking Systems, appendix B, is a balance platform and software package that can provide objective and valid balance assessments that can be used in a clinical and laboratory setting (Goble, 2015). The software component, Explore Balance, was used to evaluate dependent variables such as total sway, distance (traveled away from COP), frequency, velocity, root mean square anterior-posterior, root mean square medial-lateral, excursion anterior-posterior, excursion medial-lateral, and 95% confidence interval area over an eyes open quiet stance condition and an eyes closed quiet stance condition.

Star Excursion Balance Test. The modified star excursion balance test, appendix D, was another instrument used during the testing procedures (Hertel, 2006). This test involved the use of three standard tape measures taped to the ground in the shape of a “Y”. The directions in which each subject had to reach were anterior, posterior-lateral, and posterior-medial which were modified from the original eight-direction reach (Hertel, 2006). The individual performing this test was asked to stand with one foot planted in the center of the “Y” and was instructed to reach with their opposite foot as far as they could in the three directions.

Biodex Balance System SD (Biodex Medical Systems, Shirley, NY). The Biodex Balance System SD, appendix C, contains a stationary base with a moveable platform capable of both testing and training balance. The system has five different balance-testing options and five different balance-training options. For the purpose of this study, the testing option that was selected was the Limits of Stability (LOS) test.

Quadmill™. The Quadmill™, appendix A, is a piece of exercise equipment that works to train lower extremity muscles and was used as the intervention method. This machine contains an oscillating, flat platform where the individual stands and functions by rotating in an ellipse forcing the individual to complete repeated squat movements.

Ratings of Perceived Exertion- (Young Enterprises, Inc. Lansing, KS). Rating of perceived exertion (RPE) is used to gauge how an individual feels during an exercise. The scale ranges from six to twenty, with six being considered no exertion and twenty being maximal exertion. This scale is useful as a reference for appropriating exercise intensities while training individuals.

Design and Procedures

The present study was a six-week training intervention using the Quadmill™ with repeated measures at the pre-intervention, mid-intervention, and post-intervention assessing changes in balance between the experimental and control groups (I_1, I_2, and C_1). Balance was assessed using the Balance Tracking System, star excursion balance test, and the Biodex balance system. Independent variables include time and training group. Dependent variables are presented in Table 1.

Testing

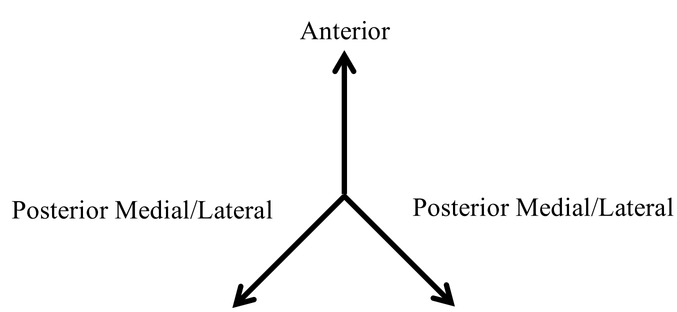
After the second round of recruitment, 30 individuals were selected and agreed to participate in this study. These 30 individuals were then randomly placed in groups through the use of a random number generator, (GraphPad Software, 2017). Prior to the start of the pre-test, each subject completed and signed an informed consent document in accordance with SUNY Cortland's IRB (appendix F). After reviewing the document the subjects were instructed to go to the Balance Tracking Systems station.

Balance Tracking Systems - Explore Balance. Before stepping onto the platform, the researcher entered in height and weight values as provided by the subject. After this information was entered into the software, the researcher then calibrated the force plate. Following the on-screen prompt, the researcher selected the "calibrate" option and waited five seconds to allow the calibration to finish. After calibration was complete, the researcher instructed the subject to stand in the center of the platform with their feet shoulder width apart. The researcher informed the subject that testing was about to begin and selected "test balance". Each trial was completed in succession without the subject stepping off of the platform. Each individual completed four trials with their eyes open and then four trials with their eyes closed. During the eyes open condition, subjects were asked to look directly at a dot drawn on the white board. Trials were nullified if the individual talked during a trial and the trial started over. While standing, the software gathered data as presented in Table 1.

Biodex Balance System- Balance System SD. Subjects at this station were asked to select the "limits of stability balance test" and follow the prompts on screen. Each subject was then instructed to stand in the center of the platform with their feet shoulder width apart and adjusted their footing so that the cursor on the screen was centered in the middle (indicated on screen). The test was performed with the individual shifting their center of gravity to move the cursor in whichever direction to meet a specified goal on screen. The test consisted of three trials with each trial lasting approximately 30-45 seconds. After completing the test, the individual selected the "results" tab on the screen to view their results while the researcher recorded the scores on the data sheet (see appendix I).

Star Excursion Balance Test. Next the individual performed the star excursion balance test, with the modification of reaching in the anterior, posterior-medial, and posterior-lateral directions. The "Y" was created using three tape measures constructed with the origin placed at the intersection of the three tapes. From the origin, the anterior direction was placed at 90^{o} with each of the other directions placed at 225^{o} and 315^{o}. For this test, the individual was instructed to stand with one foot placed in the center of the "Y".

Figure 2. Star Excursion Balance Test



Before the test began, each subject had six practice attempts with each foot in all directions (Hertel, 2006). Once the practice was completed, each subject was instructed by the head researcher which directions they were to reach and with which foot. The direction and foot each subject was instructed to reach with was randomized from subject to subject. The subjects were instructed to reach out and tap with one foot as far as they could while maintaining balance and return to the center. If the subject could not maintain their balance then that trial was nullified and they were asked to repeat. The instructions for each direction were identical. Each reach distance was measured, in centimeters, with tape measures taped on the ground and recorded by the researcher, appendix H. The distances of the three attempts were averaged together and that average served as the distance reached during the statistical analysis. Lower limb lengths were measured and recorded after completing the final trial and used in the calculation to normalize each value (Gribble, 2003).

Intervention

Quadmill. This study was a six-week training intervention consisting of two training days per week totaling 12 Quadmill training sessions and three balance testing sessions. Participants were assigned to one of two training groups (I_1 or I_2) or a control group (C_1). I_1 completed four sets of 45-second bouts at a 38 rpm setting while facing forward on the Quadmill. I_2 completed four sets of 45-second bouts at a 38 rpm setting while facing forward, then to the right, then backwards, and then to the left on each successive set on the Quadmill. When each subject arrived for training they were instructed to begin exercising immediately. They were instructed to stand comfortably on the platform with their feet shoulder width apart. Each subject was instructed to begin the exercise with their hands on the safety rails on either side of them for safety precaution. The researcher then selected the intensity and started the machine. As the machine began to rotate and the intensity reached 38 rpm, the subjects were allowed let go of the rails. As the intervention progressed, subjects were advised to hold on the rails less and less. Each set lasted 45-seconds and the subjects were given a 90 second rest interval in between each set where RPE was assessed and recorded.

Data Processing

The data were analyzed using SPSS version 23. A series of two-way mixed method ANOVAs were conducted to determine if an interaction effect existed between time (pre/mid/post) and experimental group (I_1, I_2, C_1) for the various dependent variables shown in table 1. When a significant interaction effect was present, simple main effects for time and condition were analyzed. Post-hoc analyses were used to determine where significant differences lie for all dependent variables.

Chapter 4

Results

The purpose of this study was to examine the effects of a training intervention using a lower body exercise machine (Quadmill) on balance in healthy college age individuals. This study's aim was to determine if a six-week training program using the Quadmill would lead to improved balance. Balance was assessed using three separate balance-testing instruments; Balance Tracking Systems (BTS), the modified star excursion balance test (SEBT), and the Biodex balance system (BD). Over the course of the intervention subjects completed 12 training sessions (2x/week) and three balance testing sessions. The goal of the intervention was to see improved results in each of the balance measures, presented in Table 1, from pre-testing to post-testing.

Results

A two-way mixed methods ANOVA was conducted to examine the effects of intervention group and time on 26 dependent variables, shown in Table 1. There was no significant group by time interactions for any of the 26 variables listed in Table 1 ($p > .05$). Additionally, there were no significant differences among groups I_1, I_2, and C_1 for any dependent variable ($p > .05$).

Table 2.
Root Mean Square Medial Lateral with Eyes Open

		Avg. RMS ML (cm)					
		Pre-test		*Mid-test*		*Post-test*	
Group	n	M	SD	M	SD	M	SD
$I_1^{a,c}$	9	.29	.12	.18	.08	.15	.04
$I_2^{a,c}$	10	.34	.07	.26	.28	.14	.03
$C_1^{a,c}$	9	.38	.08	.21	.08	.17	.10

Note: RMS= root mean square, ML=medial lateral, a= significant differences between pre-test and mid-test, b=significant differences between mid-test and post-test, c=significant differences from pre-test to post-test.

There were significant differences in nine of the dependent variables for time main effects ($p < .05$).

RMS ML EO main effect (F = 18.141, $p < .01$, $n^2 = 0.411$). Pairwise comparisons for the significant main effect (time) and RMS ML indicate all participants were .119 cm higher from mid-test to pre-test ($p = .006$, 95% CI, .030 lower bound, .208 upper bound) and were .183 cm higher from post-test to pre-test ($p = .000$, 95% CI, .137 lower bound, .229 upper bound). There was no statistically significant difference between the mid-test and post-test ($p = .270$). Group means and standard deviations, as shown in Table 2, indicate improved scores from pre-test to post-test.

Table 3.
Excursion Medial Lateral with Eyes Open

		Avg. EXC ML (cm)					
		Pre-test		*Mid-test*		*Post-test*	
Group	n	M	SD	M	SD	M	SD
$I_1^{a,c}$	9	1.4	.52	.86	.33	.78	.23
$I_2^{a,c}$	10	1.5	.34	1.1	.63	.72	.16
$C_1^{a,c}$	9	1.7	.30	1.1	.34	.85	.43

Note: EXC= excursion, ML= medial lateral, a= significant differences between pre-test and mid-test, b=significant differences between mid-test and post-test, c=significant differences from pre-test to post-test.

EXC ML EO Main effect (F = 42.204, $p < .01$, $n^2 = .619$). Pairwise comparisons for the significant main effect (time) and EXC ML indicate all participants were .578 cm higher from mid-test to pre-test ($p < .01$, 95% CI, .350 lower bound, .805 upper bound) and was .806 cm higher from post-test to pre-test ($p < .01$, 95% CI, .604 lower bound, 1.009 upper bound). There was no statistically significant difference between the mid-test and post-test ($p = .102$). Group means and standard deviations, as shown in Table 3, show decreased excursion medial-laterally from pre to mid to post-test indicating improvement during the intervention.

Table 4.
Root Mean Square Medial Lateral with Eyes Shut

		Avg. RMS ML (cm)					
		Pre-test		*Mid-test*		*Post-test*	
Group	n	M	SD	M	SD	M	SD
$I_1^{a,c}$	9	.35	.10	.20	.09	.16	.06
$I_2^{a,c}$	10	.36	.13	.19	.10	.14	.05
$C_1^{a,c}$	9	.44	.16	.50	.17	.47	.27

Note: RMS= root mean square, ML= medial lateral, a= significant differences between pre-test and mid-test, b=significant differences between mid-test and post-test, c=significant differences from pre-test to post-test.

RMS ML ES Main effect (F = 37.621, $p < .01$, $n^2 = .591$). Pairwise comparisons for the significant main effect (time) and RMS ML ES indicate all participants were .164 cm higher from mid-test to pre-test ($p < .01$, 95% CI, .091 lower bound, .237 upper bound) and were 1.002 cm higher from post-test to pre-test ($p < .01$, 95% CI, .696 lower bound, 1.308 upper bound). There was no statistically significant difference between the mid-test and post-test ($p = .085$). As shown in Table 4, group means and standard deviations show a decrease in root mean square values indicating an improvement over the intervention.

Table 5.
Excursion Medial Lateral with Eyes Shut

		Avg. EXC ML(cm)					
		Pre-test		*Mid-test*		*Post-test*	
Group	n	M	SD	M	SD	M	SD
$I_1^{a,c}$	9	1.7	.44	1.1	.50	.93	.35
$I_2^{a,c}$	10	.35	.13	.19	.10	.14	.05
$C_1^{a,c}$	9	2.1	.41	1.2	.72	.91	.48

Note: EXC=excursion, ML= medial lateral, a= significant differences between pre-test and mid-test, b=significant differences between mid-test and post-test, c=significant differences from pre-test to post-test.

EXC ML ES Main effect (F = 36.437, $p < .01$, $n^2 = .584$). Pairwise comparisons for the significant main effect (time) and EXC ML ES indicate all participants were .737 cm higher from mid-test to pre-test ($p < .01$, 95% CI, .434 lower bound, 1.040 upper bound) and were 1.002 cm higher from post-test to pre-test ($p = .000$, 95% CI, .696 lower bound, 1.308

upper bound). There were no statistically significant differences between the mid-test and post-test (p = .139). Group means and standard deviations, as shown in Table 5, show a decrease in excursion medial lateral from pre to mid to post-test.

Table 6.
Right Foot Reach Posterior Lateral Normalized

		Avg. RFR PL (cm/cm)					
		Pre-test		*Mid-test*		*Post-test*	
Group	n	M	SD	M	SD	M	SD
I_1 [a,b,c]	9	.84	.08	.92	.08	.96	.07
I_2 [a,b,c]	10	.79	.05	.90	.08	.92	.08
C_1 [a,b,c]	9	.84	.12	.86	.10	.90	.08

Note: RFR= right foot reach, PL= posterior lateral, a= significant differences between pre-test and mid-test, b=significant differences between mid-test and post-test, c=significant differences from pre-test to post-test.

RFR PL Main effect (F = 31.784, p = .000, n^2=.560). Pairwise comparisons for the significant main effect (time) and RFR PL indicate all participants were .072 cm higher from mid-test to pre-test (p < .01, 95% CI, .032 lower bound, .111 upper bound), .105 cm higher from post-test to pre-test (p = .000, 95%, .145, .066) and was .034 cm higher from mid -test to post-test (p = .000, 95%, .056, .011). All groups showed improvements in mean values for posterior lateral reach with their right foot from pre-test to post-test, as shown in Table 6.

Table 7.
Right Foot Reach Posterior Medial Normalized

		Avg. RFR PM (cm/cm)					
		Pre-test		*Mid-test*		*Post-test*	
Group	n	M	SD	M	SD	M	SD
I_1 [a,c]	9	.93	.05	1.0	.05	.99	.07
I_2 [a,c]	10	.91	.09	.99	.10	1.0	.09
C_1 [a,c]	9	.93	.08	.99	.10	.90	.09

Note: RFR= right foot reach, PM= posterior medial, a= significant differences between pre-test and mid-test, b=significant differences between mid-test and post-test, c=significant differences from pre-test to post-test

RFR PM Main effect (F = 25.83, p < .01, n^2 = .508). Pairwise comparisons for the significant main effect (time) and RFR PM indicate all participants were .074 cm higher from mid-test to pre-test ($p < .01$, 95% CI, .049 lower bound, .099 upper bound) and was .055 cm higher from post-test to pre-test ($p < .01$, 95% CI, .022 lower bound, .088 upper bound). There was no statistically significant difference between the mid-test and post-test. All groups showed improvements in mean values in posterior medial reach with the right foot from pre to mid-test, but only I_2 saw continued improvement from the mid-test to the post-test, as shown in Table 7.

Table 8.
Left Foot Reach Posterior Lateral Normalized

		Avg. LFR PL (cm/cm)					
		Pre-test		*Mid-test*		*Post-test*	
Group	n	M	SD	M	SD	M	SD
$I_1^{a,}$	9	.84	.12	.90	.09	.92	.06
$I_2^{a,}$	10	.82	.05	.89	.08	.83	.07
$C_1^{a,}$	9	.81	.09	.89	.06	.89	.07

Note: LFR= left foot reach, PL= posterior lateral, a= significant differences between pre-test and mid-test, b=significant differences between mid-test and post-test, c=significant differences from pre-test to post-test.

LFR PL Main effect ($F = 3.713$, $p = .031$, $n^2 = .129$). Pairwise comparisons for the significant main effect (time) and LFR PL indicate all participants were .074 cm higher from mid-test to pre-test ($p < .01$, 95% CI, .035 lower bound, .113 upper bound). There were no significant differences between mid-test and post-test ($p = 1.000$) and pre-test to post-test ($p = .280$). All groups saw improvements from pre-test to mid-test, but only I_1 and C_1 showed improvements from the mid-test to post-test as shown in Table 8.

Table 9.
Left Foot Reach Posterior Medial Normalized

		LFR PM (cm/cm)					
		Pre-test		*Mid-test*		*Post-test*	
Group	n	M	SD	M	SD	M	SD
$I_1^{a,c}$	9	.95	.06	1.0	.05	1.0	.07
$I_2^{a,c}$	10	.89	.08	.96	.09	1.0	.08
$C_1^{a,c}$	9	.92	.07	.99	.07	.97	.09

Note: LFR= left foot reach, PM= posterior medial, a= significant differences between pre-test and mid-test, b=significant differences between mid-test and post-test, c=significant differences from pre-test to post-test.

LFR PM Main effect (F = 20.764, $p < .01$, $n^2 = .454$). Pairwise comparisons for the significant main effect (time) and LFR PM indicate all participants were .066 cm higher from mid-test to pre-test ($p < .01$, 95% CI, .033 lower bound, .099 upper bound) and was .074 cm higher from post-test to pre-test ($p < .01$, 95% CI, .039 lower bound, .108 upper bound). There were no statistically significant differences between the mid-test and post-test (p = 1.000). All groups saw improvements in mean performance scores from the pre-test to mid-test but only I_2 experienced improvement to the post-test, as shown in Table 9.

Table 10.
Biodex Overall Performance Mean Scores

		BD OV					
		Pre-test		*Mid-test*		*Post-test*	
Group	n	M	SD	M	SD	M	SD
I_1[a,c]	9	56	9.9	59	15	67	11
I_2[a,c]	10	58	10	59	9.7	69	10
C_1[a,c]	9	55	10	69	13	72	13

Note: BD= Biodex, OV=overall, a= significant differences between pre-test and mid-test, b=significant differences between mid-test and post-test, c=significant differences from pre-test to post-test.

BD OV Main effect (F = 19.514, $p < .01$, $n^2 = .438$). Pairwise comparisons for the significant main effect (time) and BD OV indicate all participants were 12.730 cm higher from post-test to pre-test ($p < .01$, 95% CI, 8.008 lower bound, 17.451 upper bound) and was 6.859 cm higher from post-test to mid-test (p = .002, 95% CI, 2.387 lower bound, 11.332 upper bound). There was no statistically significant difference between pre-test and mid-test (p = .075). All groups experienced improvements in mean overall performance scores from pre-test mid-test to post-test, as shown in Table 10.

Chapter 5

Summary, Conclusions, Implications, and Recommendations

Summary

The purpose of this study was to observe and compare the effects of two separate training interventions using the Quadmill™ to a control group. It was hypothesized that both experimental groups (I_1 and I_2) would experience improvements in all balance measures whereas the control would remain at baseline level throughout the intervention. It was secondarily hypothesized that I_2 would experience greater improvements than I_1 in these measures due to the nature of the exercise protocol. Data was collected using three systems; Balance Tracking Systems, Star Excursion Balance Test, and the Biodex Balance system. The balance measures from these three systems are presented in Table 1. A two-way mixed methods ANOVA revealed there were no significant group by time interactions for any dependent variable. Results showed no significant main effect for group. Further analysis indicated a main effect for time in nine of the 26 dependent variables with a statistical significance for each of $p < .05$.

Discussion

To begin this intervention, 30 individuals were selected to participate after the second round of recruitment was completed. Within the first week of training, one subject dropped out due to chronic illness. Another individual was forced to drop out just before the post-test due to an injury occurring outside the realm of the study. Including these dropouts, 28 individuals completed the study. Out of 19 individuals who comprised the experimental groups, 18 individuals completed all 12 training sessions with one individual missing one session due to illness. This indicates that there is high compliance when exercising on the

Quadmill^{TM} twice per week for six weeks.

The outcome of the present study varied in terms of expected and observed results. It was hypothesized that both experimental groups would see improvements in all outcome measures with no changes occurring in the control group measure. The secondary hypothesis was that I_2 would see greater improvements than both I_1 and C_1. Results indicated there were no significant group by time interactions for any of the 26 balance measures recorded. Nine of these variables showed a significant difference over time, from pre-test to mid-test to post-test in all participants. There are a few factors that may have influenced the results. Previous literature has shown significant learning effects in subjects completing balance testing and training on different devices (McKeon et al 2008, Orrell, 2006, Yaggie, 2006). No significant group by time interactions may be due to significant main effects for time, improvements in all groups for nine measures, small sample sizes that did not allow for differences between groups to be observed, learning that may have occurred, additional training outside of the study, or an ineffective training intervention.

Improvements in reach distances for the SEBT after Quadmill^{TM} training were greater, on average, for the experimental groups in the posterior lateral and posterior medial directions. This is consistent with some of the literature concerning neuromuscular training and performance on the SEBT (Filipa, 2010). Greater improvements in the experimental groups, as indicated in tables 6-9 may be the product of the adaptations to the training regimen.

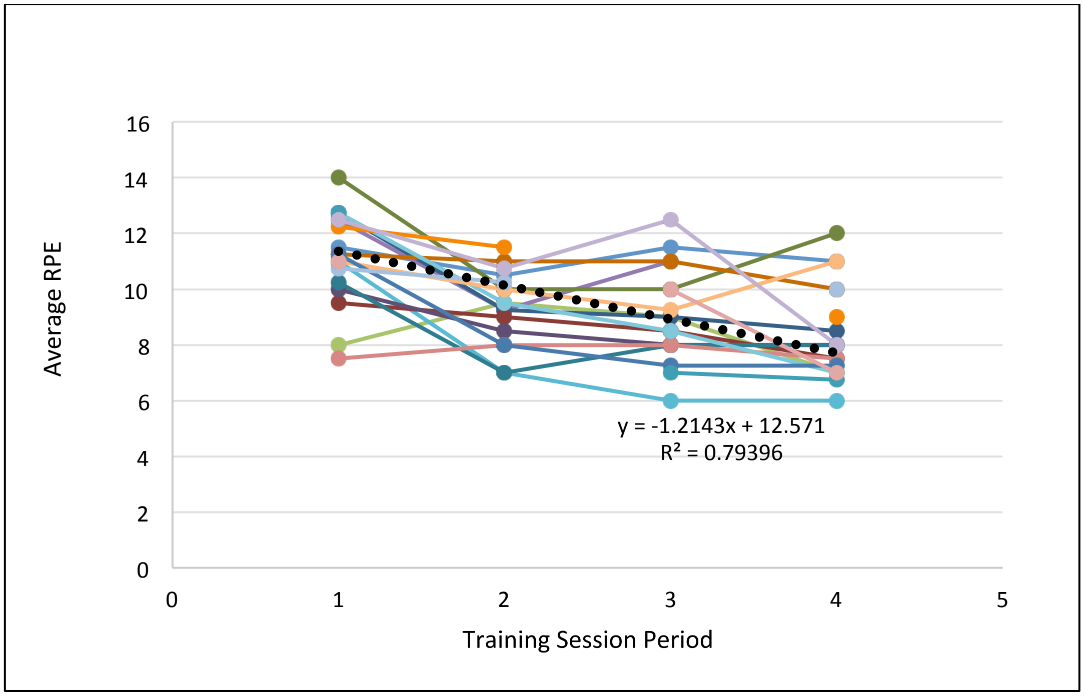


Figure 3. Average RPE of training subjects after training day 1 (1), before mid testing (2), after mid testing (3), and after training day 12 (4).

As described in figure 3, as training sessions increased, RPE decreased on average for all 19 subjects. This trend indicates a training effect on each of the subjects from exercising on the Quadmill™.

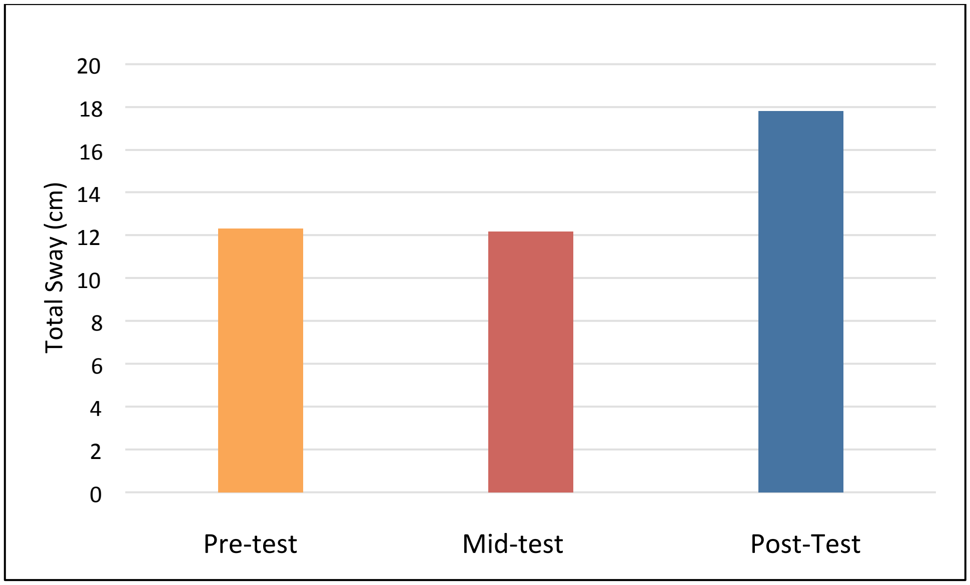


Figure 4. Average Total Sway with eyes open from pre-test to mid-test to post-test

Results showed no group by time interaction or group main effect for any dependent variable. This appears to be due to inconsistent performance by subjects in all three groups. Inconsistent performance was observed in the results of the post-test. Figure 4 shows the change that was seen during post-testing in total sway with eyes open. From pre-test to mid-test, performance in this variable remained steady. When comparing mid-test to post-test, the score increased from about 12 cm to about 18cm. The reason for this change is multifaceted. Timing alone of the post-test could have been a contributing factor. Post-testing occurred during the week of final examinations. Numerous subjects completed their post-testing with little sleep and were pre-occupied with their course work to concentrate fully on the test. Other subjects admittedly were not feeling well as a result of social activities they took part in the night before their testing day.

Other confounding factors that could have affected these results include the diet and activity level of each subject. Because there was no control for diet and activity, levels of each differed from subject to subject. There were some cases where subjects, while either training or completing testing, complained of not eating prior to their sessions, which could influence motivation and certainly energy levels. Some individuals consumed caffeine during training and testing while others did not. Some subjects completed either training or testing feeling tired and sore from exercising outside of the study. This appears to be the most plausible explanation for the observed improvements within the control group (C_1). These, while hard to determine the exact influence, were a factor especially if the muscle soreness deterred them from putting forth maximal effort as well as negatively impacting their performance on the tests. Lastly, a relatively small sample size may have limited the variance within each group and in effect may have impacted the results.

The results of this study do not indicate any evidence that the Quadmill™ directly improved balance. The results show that exercising on the Quadmill™ twice per week for six weeks improved scores on nine variables over time, as shown in Table 1. What is clear is that a combination of Quadmill™ training and balance testing effect different components of balance. Exactly which muscles the Quadmill™ effects most directly needs to be further examined.

Conclusions

It was concluded from this study that:

1. There was no difference between the two Quadmill™ training methods (I_1, I_2) on balance after six weeks of training.
2. There was no difference between the two Quadmill™ training methods (I_1, I_2) and the control group (C_1) after six weeks of training.
3. Quadmill™ training resulted in increased reach distances in both the posterior lateral and posterior medial directions for both limbs during the SEBT.

4. Exercising twice per week for six weeks on the Quadmill^{TM} resulted in measureable training adaptations in healthy college-aged individuals.

Implications and Recommendations

Results of this study are relevant to clinicians and trainers. Both the Star Excursion Balance Test and Biodex Balance System are widely used in both clinical and athletic areas of research. A learning effect may have occurred in each test and may have influenced the results. This effect needs to be taken into consideration when choosing the precise test to evaluate balance. In order to minimize this effect, test and re-test protocols to evaluate true baseline performance scores should be considered. It is recommended that the primary researchers perform intra-reliability tests to ensure accuracy during the data collection and to minimize data collection errors. It is also recommended that other confounding factors such as sleep deprivation and alcohol consumption be monitored throughout the study as these can influence the results of the study.

Exercising on a Quadmill^{TM} can provide adequate resistance training resulting in adaptations within the body. It is unknown which muscles are impacted by Quadmill^{TM} training and how they directly relate to improving balance. It is recommended that these unknowns be further investigated.

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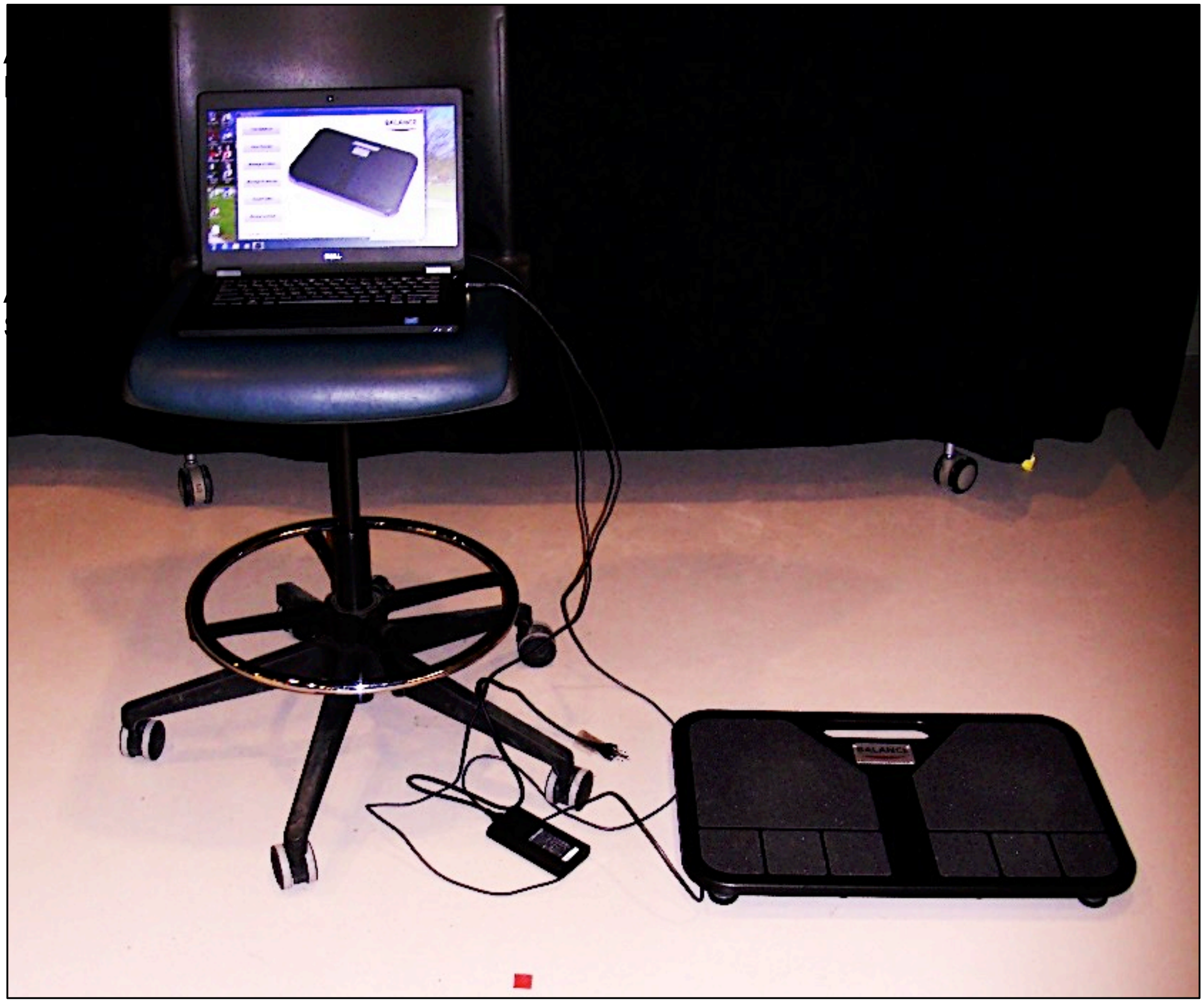
Appendix A
The Quadmill™

Appendix B
Balance Tracking Systems- Force Plate and Software



Appendix C
Biodex Balance System SD

Appendix D
Star Excursion Balance Test

Anterior

Posterior Medial

Posterior Lateral

Appendix E

Contact Information Sheet

"Effects of Quadmill™ training on balance: An intervention Study"

If you are interested in participating in the study mentioned above, sign up below

Any questions about the study, contact AJ Generali

Alexander.generali@cortland.edu

Name	**Email**

Appendix F

Informed Consent

State University of New York College at Cortland

Informed Consent

The research study that you have been asked to participate, "Effects of Quadmill™ training on balance: An intervention study" in is being conducted by AJ Generali of the Kinesiology Department at SUNY Cortland. He requests your informed consent to be a participant in the study described below. The following information is provided to help you make an informed decision about whether or not to participate.

Head Researcher- AJ Generali Chair- Dr. Jeff Bauer

Committee members- Dr. Larissa True & Dr. Mark Sutherlin

Please feel free to ask about the project, its procedures, or its objectives.

Purpose:

The purpose of this study is to investigate the potential benefits of Quadmill™ training on balance.

Procedures:

Participation in this study is voluntary and you have the right to withdraw at any time without penalty. You have the right to withdraw from any physical task at any point. If you begin answering questions and realize for any reason that you do not want to continue, you are free to withdraw from the study. Additionally, you may ask the researcher to destroy any responses you may have given.

You will be asked to participate in a total of 12 days of exercise on the Quadmill™ over the course of six weeks. Pre-testing will be conducted prior to the start of the first training day with a mid-test day after three weeks and post-test immediately following the last training day. Each balance testing day will consist of identical procedures involving different tests of balance measured through the Balance Tracking Systems force plate, the Star excursion balance test, and Biodex balance systems. You will be randomly assigned to one of three training groups; Quadmill™ training 1 (I1), Quadmill™ training 2 (I2), or control 1 (C1). The training will consist of four 30 second bouts on the Quadmill™, with I1 training group facing forward for four sets and I2 changing their orientation from forward, to the right, to backwards, and to the left.

Before agreeing to participate you should know that:

A. Inclusion/Exclusion Criteria

Healthy college-aged subjects without injuries sustained six months prior to this study will be allowed to participate. If you have certain preexisting injuries, such as lower limb injuries or experienced head trauma within the past six months you will be excluded from this study. You should be at least 18 years of age but no older than 25 years of age. Upon consent, you will then complete the inclusion/exclusion screening document to ensure you meet the participation requirements.

B. Benefits and Compensation

Participating in this study may result in some participants experiencing an improvement in lower limb muscular endurance and improvements in balance.

C. Confidentiality

All information and results regarding this study will be kept on a safe and secured laptop. Your identity will be coded to ensure anonymity. All files will be stored on this particular laptop and are to only be accessed by those directly involved with the study.

D. Risks

The risks associated with this study are those commonly associated with moderate exercise bouts, for example potential muscular fatigue, soreness and discomfort. Cardiovascular fatigue may be encountered as this exercise involves some cardiovascular work. These conditions are classified as mild and, overall, minimal risk is involved with this experiment.

E. Contact Information

If you have any questions concerning the purpose or results of this study, you may contact AJ Generali at 518-817-7465 or at alexander.generali@cortland.edu. If you have questions about your rights as a participant in this study, general questions, complaints, or concerns you would like to discuss with someone uninvolved in the research project, contact the SUNY Cortland Institutional Review Board, Miller Building Room 402, at 607-753-2511, or by email at irb@cortland.edu

AGREEMENT

I am fully aware of the nature and extent of my participation in this project as stated above and the possible risks associated with it. I hereby agree to participate in this project. I acknowledge that I have received a copy of this consent statement

______________________________ __________

(Signature of Participant) (Date)

______________________________ __________

(Printed Name of Participant) (Date)

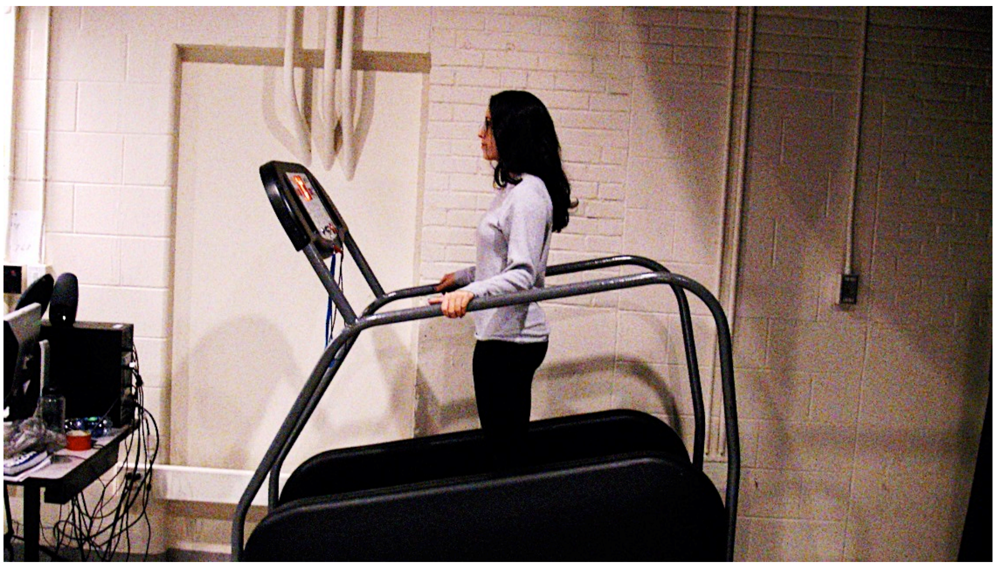
______________________________ __________

(Signature of person obtaining consent) (Date)

Appendix G
Participation Flyer

"Effects of Quadmill™ training on balance: An intervention study"

Interested in exercising on a unique machine?



The Quadmill™ is a piece of exercise equipment that works to eccentrically train the lower body

Looking to change or modify your current exercise routine AND participate in research?

Contact AJ Generali at alexander.generali@cortland.edu if interested!

This study has been approved by the SUNY Cortland IRB. If you have questions about your rights as a participant in this study, general questions, complaints, or concerns you would like to discuss with someone uninvolved in the research project, contact the SUNY Cortland Institutional Review Board, Miller Building Room 402, at 607-753-2511, or by email at irb@cortland.edu

Appendix H
SEBT Data Collection Sheet

I.D.____________________________ Pre-Test/Mid-test/Post-test

Date:___________________________

Right Foot Reach

Trial	*Anterior*	*Posterior-Lateral*	*Posterior-Medial*
Trial 1			
Trial 2			
Trial 3			
Average			

Left Foot Reach

Trial	*Anterior*	*Posterior-Lateral*	*Posterior-Medial*
Trial 1			
Trial 2			
Trial 3			
Average			

Appendix I
Biodex Data Collection Sheet

I.D.______________________ Pre-test/Mid-test/Post-test

Limits of Stability Test Results

Time to Complete:______________________

Direction Control	Actual	Goal
Overall	_____________	_____________
Forward	_____________	_____________
Backward	_____________	_____________
Left	_____________	_____________
Right	_____________	_____________
Forward/Left	_____________	_____________
Forward/Right	_____________	_____________
Backward/left	_____________	_____________
Backward/right	_____________	_____________

Appendix J
RPE Data Collection Sheet

I.D.___________________________

Session 1 Date:__________________

Rest Intervals	RPE (6-20)
Rest 1	
Rest 2	
Rest 3	
Rest 4	

Session 2 Date:__________________

Rest Intervals	RPE (6-20)
Rest 1	
Rest 2	
Rest 3	
Rest 4	

Session 3 Date:__________________

Rest Intervals	RPE (6-20)
Rest 1	
Rest 2	
Rest 3	
Rest 4	

Session 4 Date:__________________

Rest Intervals	RPE (6-20)
Rest 1	
Rest 2	
Rest 3	
Rest 4	

Session 5 Date:__________________

Rest Intervals	RPE (6-20)
Rest 1	
Rest 2	
Rest 3	
Rest 4	

Session 6 Date:__________________

Rest Intervals	RPE (6-20)
Rest 1	
Rest 2	
Rest 3	
Rest 4	

Session 7 Date:_________________

Rest Intervals	RPE (6-20)
Rest 1	
Rest 2	
Rest 3	
Rest 4	

Session 8 Date:_________________

Rest Intervals	RPE (6-20)
Rest 1	
Rest 2	
Rest 3	
Rest 4	

Session 9 Date:_________________

Rest Intervals	RPE (6-20)
Rest 1	
Rest 2	
Rest 3	
Rest 4	

Session 10 Date:_________________

Rest Intervals	RPE (6-20)
Rest 1	
Rest 2	
Rest 3	
Rest 4	

Session 11 Date:_________________

Rest Intervals	RPE (6-20)
Rest 1	
Rest 2	
Rest 3	
Rest 4	

Session 12 Date:_________________

Rest Intervals	RPE (6-20)
Rest 1	
Rest 2	
Rest 3	
Rest 4	

Appendix K

I_1 Average Means for all 26 dependent variables

Intervention group 1

		I_1					
		Pretest		*Midtest*		*Posttest*	
Variable	n	M	SD	M	SD	M	SD
Total Sway EO	9	11.75	1.7	11.55	2.7	17.8	4.3
Velocity EO	9	.8167	.126	.833	.17	.8922	.216
Distance EO	9	.3456	.141	.3789	.109	.4044	.138
Frequency EO	9	.433	.154	.3956	.104	.4033	.114
Root Mean Sq. AP EO	9	.2933	.11554	.3789	.13596	.4433	.15859
Root Mean Sq. ML EO	9	.2922	.12091	.1833	.08746	.1522	.04055
95% CI Interval EO	9	.7044	.37971	1.0156	.70244	1.2244	.58756
Excursion AP EO	9	1.3489	.39810	1.5911	.49771	2.0000	.61266
Excursion ML EO	9	1.4389	.52572	.8689	.33213	.7822	.23968
Total Sway ES	9	24.3112	6.79491	23.6862	4.94432	25.7844	9.01535
Velocity ES	9	1.2157	.34019	1.1836	.24803	1.2889	.45162
Distance ES	9	.4426	.10728	.4943	.20488	.4833	.21095
Frequency ES	9	.4654	.13909	.4433	.16358	.4744	.14553
Root Mean Sq. AP ES	9	.3972	.09488	.5210	.24934	.5400	.23441
Root Mean Sq. ML ES	9	.3564	.10614	.2073	.09411	.1678	.06888
95% CI Interval ES	9	1.0920	.42704	1.5011	.95518	1.7944	1.43813
Excursion AP ES	9	1.8854	.33417	2.3073	.69961	2.5056	.87841
Excursion ML ES	9	1.7427	.44790	1.1030	.50092	.9389	.35016
RFR ANT Norm	9	.787	.046	.7877	.076	.7841	.072
RFR PL Norm	9	.8402	.089	.9273	.082	.962	.072
RFR PM Norm	9	.9346	.05	1.01	.05	.9954	.07
LFR ANT Norm	9	.792	.043	.784	.092	.791	.05
LFR PL Norm	9	.846	.120	.907	.098	.9223	.064
LFR PM Norm	9	.953	.066	1.02	.055	1.0129	.070
Biodex Overall Score	9	56.3	9.9	59.4	15.04	67.4	11.5
Biodex Time	9	38.6	5.4	38.3	4.8	34.8	4.8

Appendix L

I_2 Average Means for all 26 dependent variables

Intervention group 2

		I_2					
		Pretest		*Midtest*		*Posttest*	
Variable	n	M	SD	M	SD	M	SD
Total Sway EO	10	12.22	2.3	12.12	3.2	18.15	2.15
Velocity EO	10	.866	.187	.849	.205	.906	.108
Distance EO	10	.443	.106	.474	.31	.357	.086
Frequency EO	10	.337	.07	.363	.122	.4270	.06567
Root Mean Sq. AP EO	10	.3910	.10535	.4400	.18649	.3910	.08412
Root Mean Sq. ML EO	10	.3460	.07734	.2640	.28629	.1410	.03957
95% CI Interval EO	10	.9770	.43415	1.8030	2.22188	.9830	.48030
Excursion AP EO	10	1.7060	.38149	1.8890	.55553	1.7800	.34483
Excursion ML EO	10	1.5750	.34336	1.1200	.63783	.7220	.16295
Total Sway ES	10	24.4514	5.88607	24.5324	4.67905	24.8590	6.55872
Velocity ES	10	1.2228	.29490	1.2266	.23459	1.2430	.32772
Distance ES	10	.4555	.17077	.4891	.10507	.4980	.17074
Frequency ES	10	.4607	.07927	.4244	.07783	.4310	.09024
Root Mean Sq. AP ES	10	.4286	.18974	.5483	.11965	.5720	.19753
Root Mean Sq. ML ES	10	.3596	.13093	.1993	.10257	.1460	.05038
95% CI Interval ES	10	1.4936	1.32779	1.8115	.90266	1.5650	.92802
Excursion AP ES	10	2.1116	.95411	2.6773	.61611	2.7050	.86662
Excursion ML ES	10	1.8238	.73153	1.0696	.53820	.7990	.24578
RFR ANT Norm	10	.8169	.11	.7870	.06	.7966	.12
RFR PL Norm	10	.7997	.05	.9055	.08	.9277	.08
RFR PM Norm	10	.913	.09	.9932	.10	1.00	.09
LFR ANT Norm	10	.820	.10	.786	.083	.8122	.130
LFR PL Norm	10	.820	.05	.898	.086	.833	.075
LFR PM Norm	10	.898	.080	.9654	.09	1.02	.089
Biodex Overall Score	10	58.9	10.1	59.4	9.7	69.2	10.7
Biodex Time	10	40.1	6.5	37.5	5.2	37.4	6.9

Appendix M

C_1 Average Means for all 26 dependent variables

Control group 1

		I_1					
		Pretest		*Midtest*		*Posttest*	
Variable	n	M	SD	M	SD	M	SD
Total Sway EO	9	12.94	3.27	12.80	2.66	17.4	6.7
Velocity EO	9	.927	.216	.885	.172	.872	.338
Distance EO	9	.44	.107	.441	.1926	.394	.213
Frequency EO	9	.3760	.13946	.3630	.12248	.3690	.20273
Root Mean Sq. AP EO	9	.3640	.09845	.4440	.20903	.4100	.22949
Root Mean Sq. ML EO	9	.3800	.08367	.2140	.08884	.1760	.10352
95% CI Interval EO	9	1.0710	.40137	1.4450	.96919	1.4500	1.20006
Excursion AP EO	9	1.6820	.42150	1.8560	.75059	1.8390	.97716
Excursion ML EO	9	1.7650	.30222	1.0570	.33958	.8560	.43308
Total Sway ES	9	25.7759	7.14624	22.3107	5.01786	22.3360	9.03582
Velocity ES	9	1.2895	.35760	1.1151	.25156	1.1170	.45240
Distance ES	9	.5293	.17861	.4879	.18754	.4210	.24946
Frequency ES	9	.4381	.14132	.4247	.18299	.4350	.22152
Root Mean Sq. AP ES	9	.4427	.16146	.5015	.17242	.4690	.27835
Root Mean Sq. ML ES	9	.4407	.12531	.2581	.16848	.1620	.09004
95% CI Interval ES	9	1.6719	.80981	1.7367	1.05730	1.7350	1.70818
Excursion AP ES	9	2.0474	.55819	2.3422	.73846	2.2170	1.19598
Excursion ML ES	9	2.0936	.41398	1.2770	.72098	.9160	.48958
RFR ANT Norm	9	.7291	.09	.7356	.06	.7546	.06
RFR PL Norm	9	.8428	.122	.8651	.10	.9089	.08
RFR PM Norm	9	.932	.078	.997	.104	.950	.09
LFR ANT Norm	9	.756	.07	.752	.05	.768	.05
LFR PL Norm	9	.810	.09	.8915	.065	.898	.076
LFR PM Norm	9	.923	.078	.997	.078	.970	.09
Biodex Overall Score	9	55.3	10.7	69.3	13.1	72.1	13
Biodex Time	9	38.2	5.6	35.9	5.2	34.8	4.5

Appendix N
Pilot Study

In March of 2015, a pilot study was conducted following a similar protocol to the one outlined in the present study. This study involved four participants, three college-aged females and one college aged male, each randomly assigned to one of two training groups with no control group. The study involved just a pre-test and post-test of balance measures using the Balance tracking systems and the star excursion balance test. The intervention was two weeks in length with two training days per week using the Quadmill™ totaling four training days for the study. Each group completed four sets four 30-second bouts at a 30% graded intensity level. I_1 completed all sets facing forward where I_2 completed one set facing forward, to the right, backwards, and to the left.

Results

A series of paired sample T-tests was conducted to compare T_s eyes shut and shut, 95% CI area with eyes shut and shut, excursion anterior, posterior-medial, and posterior-lateral of all subjects pre and post intervention. A 2-way ANOVA was conducted to compare T_s eyes shut and shut, 95% CI area with eyes shut and shut, excursion anterior, posterior-medial, and posterior-lateral between both training groups pre and post intervention. Significant post-test values were found 95% CI area with eyes shut for all subjects. All other values were found to not be significant and are illustrated in tables 1, 2, and 3.

Discussion

Although there was no statistical significance found in most outcome measures, aside from 95% CI area with eyes shut, improvements in balance related measures were seen when comparing means and standard deviations. With only four sessions training on the Quadmill™, participants saw increases in balance and it can be rationalized that improvements may be seen in other populations from similar training. Due to the nature of this study, limitations existed and could explain some of the results. Limitations included a small sample size with only two participants in each group, indicated by the variance in standard deviations in the outcome measures. The sample was not homogenous in that there were three females and one male, differing anthropometrically. This limitation may have skewed data in the star excursion balance test with vastly different limb lengths and no normalization of their limbs. Because this was a pilot study, an obvious limitation was the length of the intervention. The literature suggests a six-week intervention being necessary to see improvements through training so with a longer study and intervention the results will be more conclusive.

Through only four training sessions participants did see improvements in balance. It can be rationalized that one, with more training sessions balance may be more positively affected and two, that other populations may see similar results through a similar intervention training. The training itself is not time consuming and is low impact and can be considered feasible for older populations and potentially clinical populations as well. With improved balance, elderly individuals and those in clinical population will see a decrease in falls and injuries due to falls. Many studies have been conducted to investigate strategies for fall prevention and to improve balance, however, none have methodologically paralleled this present study.

In conclusion, training for improvements in balance on the Quadmill™ is seemingly effective. Further research is required to investigate the effects of such a training intervention over longer periods of time, with changes in some of the pretesting and post-testing measure data collections needing adjustment as well. With a stronger study on the same population, college-aged students, research delving into a less healthy and adaptable population is of interest. The clinical application of this program and study is what is of most worth. Helping to find a modality better suited for clinical populations in need of improvements in balance can be extremely impactful. There are individuals struggling with the consequences of poor balance, and training on the Quadmill^{TM} may be part of a solution to these problems.