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The Quadmill: effects of eccentric training vs. concentric training on lower extremity power and anaerobic capacity 2014.

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The Quadmill^{TM}: Effects of Eccentric Training vs. Concentric Training on Lower Extremity Power and Anaerobic Capacity

by

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ABSTRACT

Training focuses on the concentric action of muscle during exercise for most exercise programs, but eccentric training may yield greater results. The Quadmill™ is a unique piece of training equipment that focuses on training the quadriceps muscle eccentrically. **Purpose:** to determine if using the Quadmill™ could increase power and anaerobic capacity to the same level, if not greater, than a standard concentric focused lower body training protocol. Participants were 44 undergraduate college students (24 Male 20 Female) **Design**: participants placed into three equal groups (Quadmill™, Lifting, Control). The two experimental groups (Quadmill™ and Lifting) underwent seven weeks of a training intervention based on group. Pre- and post-tests of power (vertical jump height and approach jump height) and anaerobic capacity (shuttle run) were used to measure performance. The Quadmill group was statistically significant from both of the other groups in terms of power after the seven weeks **Conclusion:** eccentric training with the Quadmill™ can yield greater power development than concentric training with a standard resistance training program

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CHAPTER 1

INTRODUCTION

As the sports world has evolved, athletes have turned to training as a way to increase performance and success. One of the primary methods athletes use to improve performance is resistance training. Consequently, much research focuses on how best to use resistance training to enhance athletic performance.

Statement of the Problem

Athletes are always looking for a way to improve their performance and to acquire an advantage over their competitors. Eccentric lower body training with the Quadmill™ may help athletes improve their lower body power and anaerobic capacity as effectively as or more effectively than traditional resistance training programs. The advantages of Quadmill™ training program over traditional resistance training programs include:

1. Shorter training time,
2. Decreased chance of injury by removing impact and reducing the load on the joints, and
3. Better workout routine compliance.

Purpose of the Study

The purpose of this study was to compare changes in lower extremity power and anaerobic capacity between a seven week eccentric training program of the lower extremities using an eccentric training device, the Quadmill™, and a seven week traditional resistance training program of the lower extremities.

Hypothesis

Concentric focused training with a traditional resistance training program and eccentric focused training with the Quadmill™ training system will both yield significant improvements in peak-power output and anaerobic capacity after a seven week training intervention, as measured by a standing vertical jump, an approach vertical jump, and a 160 yard shuttle run respectively. A second hypothesis was that after seven weeks the gains in all areas by the eccentric training program using the Quadmill™ will be significantly greater than the gains attained from the traditional resistance training program. A third hypothesis was that participants' compliance will be higher and total time of workout will be shorter for the Quadmill™ group than the lifting group.

Delimitations

The training protocols had an appropriate work to rest ratio to improve anaerobic systems as opposed to aerobic systems. Subjects were untrained or detrained to anaerobic or power training protocols for at least three months. Multiple trials were done for vertical jump pre-tests and the same tester was used for every test to insure reliability. The tests were done in the same location. Participants were tested on the same day of the week for pre- and post-tests and given the same instructions each time. Participants kept a log book to account for sleeping patterns, eating habits, medication, and supplementation to account for any confounding variables. Participants' weights were recorded pre- and post-tests to ensure their accuracy for Lewis power calculations.

Limitations

It was impossible to have each participant run exactly the same distance for the shuttle run test both between and within subjects. Participants did not undergo training protocols the same day nor the same time of day between and within groups due to the participants' schedules as well as the researcher's schedule. Participants chose the group they would be part of based on relative ease of adherence to the chosen training protocol, thereby enhancing compliance and yielding more useful data.

Assumptions

It was assumed that participants had similar detraining periods before pre- and post-testing to limit variation both within and between subjects. It was assumed that participants completed all training and testing protocols with the same level of motivation. It was assumed that participants had roughly the same body composition across all groups including muscle fiber types. Furthermore, it was assumed that participants lived similar life styles including, but not limited to, food, supplementation, sleep patterns, and any medications. Lastly, it was assumed that all participants were honest with filling out daily logs of nutrition, sleep, and exercise.

Definition of Terms

- *Quadmill™* – A piece of exercise equipment that eccentrically trains the lower body by having a platform oscillate while the individual keeps his/her upper body in the same location in space.
- *EPOC*- Excess Post Oxygen Consumption

- *Daily Log* – book given to participants for them to record calorie intake as well as basic circadian rhythms and any other confounding factors
- *Tendinopathies*- Diseases of a tendon that weakens it
- *HR*- Heart rate
- *Detrained or untrained*- not engaging in resistance training
- *Power*- force x velocity
- *Lewis Formula*- power in kg X m X s^{-1}= (√4.9) X Weight (kg) x (√jump height (m))
- *Approach Jump Vertical* – Vertical jump test with the participant allowed to take steps before performing the countermovement and executing the jump

Significance of the Study

In an attempt to obtain a greater understanding of athletic performance as related to power output and anaerobic capacity from training protocols, it was the goal of this study to establish whether eccentric training with the Quadmill™ is a better way to train than a traditional resistance training program. Power is an important factor in athletic performance (dependent on sport), so, research on how best to improve will yield valuable information for both athletes and coaches, and for future studies of athletic performance enhancement.

This study also investigated whether the Quadmill™ is a viable piece of training equipment for improving power and anaerobic capacity; if this is confirmed, an athlete could achieve the same if not greater results in less time by using the Quadmill™ compared to using standard resistance training (roughly 20 minutes per Quadmill™

workout, 30 minutes for standard resistance training). If the Quadmill™ workout used takes less time than the resistance training program, it may promote greater adherence and be a better way to train power and anaerobic capacity. If the results support the hypothesis, then a shorter Quadmill™ workout could be more effective than spending a greater amount of time in the gym doing a standard resistance training workout.

CHAPTER 2

REVIEW OF LITERATURE

In sport, muscular training has been a cornerstone for improvement. One of the primary ways athletes train to improve performance is through resistance-training programs. The documented ((Baechle & Earle 2008, Roche et al. 2008, Hahn et al. 2012, Friden et al. 1983) utility of this approach has opened the door for more research in resistance training and how it might best be used to optimize athletic performance. Training can be broadly divided into two categories: aerobic and anaerobic. Aerobic training is generally low-intensity (60-85% maximal heart rate), long-duration (lasting more than two minutes) exercise (Baechle & Earle, 2008). Its principal benefits include strengthening muscles involved in respiration, improving circulation efficiency, enhancing utilization of fats, and increasing mitochondrial density. This is the primary training of endurance athletes and can consist of running, swimming, or even certain kinds of weight training, such as circuit training. Training at higher percentages of resting heart rate, or above the lactate threshold, is inherently anaerobic. Anaerobic training is high-intensity (> 85% maximal heart rate), short-duration exercise (< 2 minutes), and elicits increased strength and power, muscular endurance and hypertrophy, and improved motor skill performance (Baechle & Earle, 2008). Anaerobic training can consist of weight training, plyometrics, interval training, and drills to build speed and agility (Baechle & Earle, 2008).

There are three different types of muscle contractions: concentric, eccentric, and isometric. Concentric muscle action occurs when the muscle shortens because the contractile force is greater than the resistance force. Eccentric muscle action occurs when the muscle lengthens because the contractile force is less than the resistive force. Isometric muscle action occurs when the muscle length does not change because the contractile force is equal to the resistive force (Baechle & Earle 2008). Greater forces, and thus, greater power, can be produced by eccentric contractions.

Anaerobic capacity is the body's capacity to utilize energy pathways in the absence of oxygen. By way of contrast, aerobic capacity is the body's capacity to meet the energy needs of lower intensity exercise in the presence of sufficient oxygen. Anaerobic capacity is important for brief, high-intensity activities, and is strongly correlated with power (Altug, Altug, & Altug 1987). Anaerobic capacity may be understood as the capacity to do a power exercise repetitively.

Power is one of the most sought after athletic attributes. Athletes with the most power (relative to the functional demands of their sport) are often the best athletes. Many sports demand explosive power, requiring athletes to perform an action quickly and forcefully. Consequently, power is variously defined as torque/velocity (Dos Santos, Baroni, Lanferdini, Freitas, Frasson, & Vas, 2011), force X velocity, work/time, or force X distance/time. (Coburn, 2012)

The piece of equipment that will be used to train the lower body eccentrically is the Quadmill™. The Quadmill™, which simulates backpedaling on a bicycle with both legs, is used to increase anaerobic capacity, train quadriceps muscles eccentrically, and improve strength and power.

Muscle Contraction Type

Resistance training can be broken down into three different types based on the type of contraction used; concentric, eccentric, and isometric. When a muscle contracts, it pulls on its points of attachment. Positive work is done by a muscle when it contracts and the muscle's points of attachment move in the direction of the force pulling on them; the force (muscle force) and the displacement (displacement at the point of muscle attachment) are in the same direction. The muscle shortens, and the muscle contraction is a concentric contraction. Negative work is done by a muscle when it contracts and its point of attachment moves in the opposite direction of the force pulling on it; the force and the displacement are in opposite directions. The muscle lengthens, and the muscle contraction is an eccentric contraction. Not all muscle contractions produce mechanical work. A muscle can contract and do zero mechanical work. This occurs when a muscle contracts and its points of attachment do not move relative to one another. The displacement at the point of muscle attachment is zero. The muscle length remains unchanged, and the muscle contraction is an isometric contraction (McGinnis 2005)

Based on the specificity principle of strength training, eccentric and concentric contractions stimulate muscles differently, and consequently would be expected to produce different adaptations (Hortobagyi & Hill et al. 1996). Of the three contraction types mentioned previously, eccentric contractions produce the highest absolute forces (Roig, O'Brien, Kirk, Murray, McKinnon, Shadgan & Reid 2009). Unlike concentric contractions, muscles are capable of producing more force the faster they contract eccentrically (to a point), which allows them to store kinetic energy during rapid movements, such as foot strikes during sprinting (Kent 1992). Greater increases in hypertrophy have been reported from eccentric training compared with isometric and concentric training, with the greatest increases being in the type IIA fibers (Vikne, Refnes, Ekmark, Medbo, Gundersen, & Gundersen 2006). Type IIA fibers are fast-twitch and used in power movements. In a power meta-analysis by Riog et al. 2009— *The effects of eccentric versus concentric resistance training on muscle strength and mass in healthy adults: a systematic review with meta-analysis* — strength gains from eccentric and concentric exercise were compared. Riog concluded that in all of the studies, eccentric strength gains during eccentric training programs were significantly greater than eccentric strength gain from concentric training programs. On the other hand, there were no significant differences found between gains in concentric strength regardless of program used. Eccentric contractions were also seen to produce less fatigue and better metabolic efficiency than concentric contractions. Other studies point to the relative efficacy of eccentric training for building tendon strength, explaining its status as treatment of choice for physical therapy clients with tendinopathies. (Kaux, Drion, Libertiaux, Colige, Hoffmann, Nusgens, Besancon, Forthomme, Goff, Franzen, Defraigne, Cescotto, Rickert, M., Crielaard, J., & Croisier 2012).

Eccentric training is not often emphasized as a way to train athletes. Consequently, it would not be unreasonable to expect that participants (trained or untrained) engaged in eccentric training might experience substantial gains in strength, because they would benefit from the enhanced motor unit recruitment more commonly seen in untrained subjects. Even individuals who have been resistance training for years could experience increased gains by training eccentrically as they could be considered "eccentrically untrained." They could receive many of the same gains as an untrained individual! A study done by Vikne et al., (2006) supported this finding; only eccentric training was shown to increase anatomical muscle fiber cross-sectional areas in previously resistance-trained men (Vikne et al., 2006; Kaux et al., 2012).

The downside to eccentric training is that delayed onset muscle soreness (DOMS) tends to be more pronounced as compared with isometric or concentric training (Elmer, Hahn, Mcallister, Leong, & Martin 2012; Fernandez, Bresciani, Teixeira, De, Aldo, Jimenez, Gonzalegallego, Paz, & De. 2011; Paddon-jones, Muthalib, & Jenkins 2000). Even a single bout of eccentric training differs from concentric training in terms of DOMS. However, as with other types of training stimuli, the body becomes accustomed to eccentric training's recuperative demands, and post-exercise soreness lessens over time (Friden, Seger, Sjostrom, & Ekblom 1983). Unaccustomed eccentric contractions produce transient muscle damage, soreness and force impairments. Furthermore, adaptations after eccentric training are highly specific to the velocity and type of contraction (Roig & O'Brien et al 2009). The good news is that although DOMS may be worse, training a sore muscle may enhance recovery so long as overtraining is scrupulously avoided. (Smith, Fulmer, Holbert, McCammon, Houmard, Frazer, Nsien et al. 1994).

Quadmill™

The Quadmill™ made its appearance in the fitness market in 2001. The Quadmill™ is specialized for eccentric muscle conditioning of the lower body. According to reACT, the manufacturer of the Quadmill™, it was designed to increase muscles' shock absorption, promote rapid strength gains, and develop anaerobic capacity. Use of the Quadmill™ has been shown to increase shock absorption after a ten week training program (Salci, Yildirim, Celik, Ak, Kocak & Korkusuz 2013). Exercising on the Quadmill™ requires the participant to stand on a stationary platform that oscillates in the vertical and horizontal planes. The rate of oscillation determines the intensity of the exercise. This device forces the legs to absorb energy with no impact. This is accomplished with a reverse bicycle motion done with a platform.

A study done by Howlett and Keniston in 2004 investigated the metabolic costs of using the Quadmill™. The researchers found that group mean peak heart rate (HR) and total caloric expenditure both increased linearly with exercise intensity. The group mean linear model of the cost of exercise was [Cost (kcal*min^{-1}*kg^{-1}) =.0028 Intensity (oscillations*min^{-1})-0.0839 kcal*min^{-1}*kg^{-1}]. Furthermore, large EPOC (excess post oxygen consumption) suggests the device imposes a significant anaerobic challenge. Consequently, the device appears to be best suited for sports-specific anaerobic training such as power (Howlett & Keniston 2004). The large EPOC value found in this study suggests the Quadmill™ may be used to train both anaerobic capacity and power.

Both the Quadmill™ and standard resistance training can improve anaerobic capacity and power when they are used correctly. A standard resistance training program with free weights can lead to injury if the load is too great, if the participant's form breaks from the muscles normal range of motion, or if a spotter is used who isn't experienced enough to know when to rack the weight. Resistance machines can lead to injuries as well if the load is too great or proper form isn't used. A standard resistance-training program requires multiple pieces of equipment, which is why individuals usually go to the gym to complete the program. The Quadmill^{TM} is advantageous as it uses body weight and is non-impact (feet don't come off the machine), which may reduce injury tremendously. In addition, the Quadmill^{TM} is only one piece of equipment; one wouldn't need a leg press machine, barbell, weights, etc. to complete a training program. The full program could be conducted on a single piece of equipment! Compliance in use of the Quadmill^{TM} was confirmed by the pilot study as the participants involved in the Quadmill^{TM} group missed, on average, less than one session during the whole four weeks.

Tests for Power and Anaerobic Capacity

Outside of the scientific realm, power is loosely defined as "strength, might, force" (Webster 1996). In physics, power is the amount of work done in a given amount of time with work equaling force times distance (Coburn, 2009). For this study, power will be defined in terms of how quickly weight is moved (product of force and velocity). Lower-body power may be reliably measured by a vertical jump test with a Vertec (Coburn, 2012). Any test that allows for the measurement of the components of power (force, velocity, etc.) will allow for calculation of power output (Coburn, 2009).

The Vertec (Figure 4 in Appendix A) is used to measure vertical jump height, which can in turn be used with a participant's weight in the Lewis formula to calculate power (Coburn, 2009). The Vertec measuring device is widely used and requires the participant to maximally reach for the highest vane possible they can reach. The participant then jumps and tries to touch the highest possible vain they can reach while they are in the air. The difference is recorded as vertical jump height. The Vertec is composed of 48 vanes spaced 1.27 cm apart that can be displaced by the hand. It has been compared to other measures such as a jump mat and a force platform to validate its reliability (Petushek et al., n.d.). The effective size difference between the Vertec trials in the literature was small, thus limiting the possibility for type I error and aiding in its reliability (Petushek et al., n.d.)

The 160-yard shuttle run may be used to measure anaerobic capacity. The 160-yard shuttle run measures anaerobic capacity, which in this context is defined as the total amount of work performed or energy produced by anaerobic processes during short duration, high-intensity exhaustive exercise (Green & Dawson, 1993). The shuttle test was compared with the Cunningham and Faulkerner treadmill anaerobic speed test for its reliability in quantifying anaerobic capacity (Thomas & Plowman, 2002). Findings showed there were no significant differences between the tests, and both were reliable measures of anaerobic capacity. At the same time, the Wingate Anaerobic Test was shown to be less reliable than either of the other two tests (Thomas & Plowman, 2002). For these reasons, and its ease of administration, the researcher has chosen to use the 160-yard shuttle run to test anaerobic capacity.

Conclusion

In conclusion, previously published research suggests that eccentric training is superior to concentric training for the enhancement of anaerobic power. The research into eccentric training (Dos Santos et al. 2011, Elmer et al. 2012, Fernandez-gonfalon et al. 2011, Friden et al. 1983, Hamlin et al. 2001, Kaux et al. 2012, Roig et al. 2009) has shown increases in hypertrophy, strength, power, and even tendon strength. The Quadmill^{TM} is a unique and specialized piece of training equipment that isolates the eccentric part of the body squat and can be used to obtain distinguishable results. The Quadmill^{TM} can produce increases in both anaerobic capacity and power equaling, if not surpassing, those produced by standard resistance training programs. Furthermore, because it is such a different way to train using the Quadmill^{TM} may lead to an increase in compliance.

CHAPTER 3

PILOT STUDY

A pilot study was conducted in spring 2013. The purpose of that study was to quantitatively compare gains in leg power and anaerobic capacity using the Quadmill™ with those using only a standard resistance training program, which includes significant concentric contraction.

Thirty two college undergraduates (8 female and 24 male) participated, and were randomly assigned to three groups: Quadmill™, Lifting, and Control). The two intervention groups (Quadmill™ and Lifting) trained with either the Quadmill™ or standard protocol, respectively. Pre- and post- tests of power (vertical jump height) and anaerobic capacity (shuttle run) were used to measure performance.

A one-way ANOVA was used to test for differences in vertical jump height, approach jump, and shuttle time among the three different treatment groups. There was a significant difference between shuttle time, F (2,30)= 7.75 (p=.002), and vertical jump, F (2,30)= 9.22 (p=.0008). A Bonferroni post-hoc test was run to determine the effect between groups. For the shuttle time there was a significant difference between groups one and two, F (2,30)=2.33 (p=.005), and groups one and four, F (2,30)= 2.39 (p=.01). There was no significant difference between groups two and four. For the vertical jump there was a significant difference between groups one and two, F(2,30)= -12.31 (p=.002), and groups one and four, F(2,30)= -13.13 (p=.004). There was no significant difference between groups two and four. There were no significant differences in the jump approach (p=.051).

The compliance was very good for the Quadmill™ group as the average amount of missed sessions was less than one (.34 missed sessions per person over the course of the study). Participants reported they enjoyed the workouts, as well as how little time it took to finish them (<20 minutes). Consequently, both anecdotal and statistical findings support the contention that the Quadmill™ is a valuable piece of equipment for training athletes seeking to increase lower-body power and anaerobic capacity.

Data collected in the pilot study, and anecdotal reports of its participants, were used to improve the design of the currently proposed study. The shuttle run's location was switched to on a basketball court in a gym to help insure the same weather conditions. The shuttle run was also shortened to ensure that anaerobic capacity was measured more exclusively. The vertical and approach jump testing was also conducted on a basketball court in a gym for a better surface; frictional force was too low in the pilot study, and participants reported feeling as though they could not produce maximal efforts at times due to fear of falling.

CHAPTER 4

RESEARCH MANUSCRIPT

As the sports world has evolved, athletes have turned to training as a way to increase performance and success. One of the primary ways athletes train to improve performance is with resistance training (Baechle & Earle 2008). Consequently, much research focuses on how best to use resistance training to enhance athletic performance.

The most common training method used by athletes is one henceforth referred to as the standard training program. This program uses a variety of machines that allow the athlete to isolate specific muscles and increase resistance as training progresses. For our purposes, this includes a leg press machine in addition to ones designed specifically for leg extensions, leg curls, and calf curls. Each of these machines requires significant concentric contraction (Baechle & Earle 2008).

This method of training will be contrasted with the Quadmill™. The Quadmill™ is used to increase anaerobic capacity and train quadriceps muscles eccentrically, thereby improving strength and power. Because it strongly emphasizes eccentric contraction, the Quadmill™ permits meaningful comparison with the standard training program, and consequently the efficacy of eccentric-based training of quadriceps muscles as compared with conventional approaches that strike a balance between eccentric and concentric contraction.

This study will test, specifically, power and anaerobic capacity. Average power will be calculated using the Lewis equation: weight and jump height will be used to calculate force output (Coburn, 2012). The Vertec and a measuring tape will be used to precisely and accurately quantify jump height differential using standing jump height and approach jump height. Anaerobic capacity will be measured using a 160-yard shuttle run test. All values will be measured pre-, mid-, and post-test and analyzed for significant differences.

Participants

There were 44 participants (24 Male 20 Female) recruited; each participant was an undergraduate college student having detrained for at least three months or had no previous eccentric or Quadmill™ training. Individuals with previous lower body injuries that would significantly affect their performance were disqualified. Each participant was then placed into one of three training groups: eccentric (Quadmill™) (N=16), concentric (N=17), or control (N=11). A group match design was chosen to foster greater compliance and adherence.

Experimental Design

This study was designed to assess the improvements in power and anaerobic capacity after a seven-week training protocol that involved training twice a week (training based on group and explained in detail in Tables 1 and 2 on the following pages). Participants were allowed to choose when to fulfill the required days during the week as long as there was least 48 hours between sessions. Measurements of average power (vertical jump and approach jump) and anaerobic capacity (shuttle run) were taken before the training protocol, midway, and after. The control group did not engage in resistance training for the seven-week period. Each participant was instructed to refrain from taking alcohol and caffeine as well as engaging in any activity that will cause delayed onset muscle fatigue in the lower body for a period of 48 hours prior to each test. Participants were informed about the nature and purpose of the investigation prior to giving their consent to participate in the experiment.

Eccentric Training

The eccentric training group used the Quadmill™ twice a week (Table 1).

Table 1
Training Program for Quadmill Group

Week/s	Weekly session #	Exercises	Speed (rev/min)	# Sets	Duration (s)	W/R Ratio	Load
1	1	Basic	40	4	30	1:2	BW
1	2	Basic	40	4	30	1:2	BW
1	2	Side	40	2	30	1:2	BW
2	1+2	Basic	60	5	45	1:2	BW
2	1+2	Side	60	3	45	1:2	BW
3	1+2	Basic	60	5	45	1:1.5	BW
3	1+2	Side	60	4	45	1:1.5	BW
4	1+2	Basic	70	5	45	1 :1.5	BW
4	1+2	Side	70	4	45	1:1.5	BW
5	1+2	Basic	60	4	30	1:2	25lbs
5	1+2	Side	60	2	30	1:2	25lbs
6	1+2	Basic	60	4	45	1:2	25lbs
6	1+2	Side	60	2	45	1:2	25lbs
7	1+2	Basic	70	5	45	1:3	25lbs
7	1+2	Side	70	3	45	1:3	25lbs

*BW = bodyweight, Basic = Basic Squat form, Side = Side Squat Form

*Subject to change based on ability for participants to complete training for specific days.

Concentric Training

The concentric training group went to the gym twice a week and completed the program as depicted by the training protocol below

Table 2
Training Program for Lifting Group

Exercise	Sets	Reps
Leg Press	3	15-12-10
Leg Extension	3	10
Leg Curl	2	10
Seated Calf Raise	2	12-10

*Though individuals choose their own weights, they were instructed to challenge themselves and use weights that would induce muscle failure for the set. The weight used was increased five pounds (or as much as tolerated) every other week (Baechle & Earle 2008). The exercises were always performed in this order every single time.

Testing

Before the jump testing and shuttle run took place, participants' bodyweights were accurately measured to help ensure reliability of the Lewis equation in subsequent statistical analysis. Participants were weighed using a digital Escali scale model number BFBW200.

Average power was assessed using vertical jump and approach jump tests; jump heights were measured using a Vertec (Figure 4 in Appendix A). Participants were instructed to warm up to their comfort level for all testing. Standing reach heights were first measured (in inches) against a wall along with the individual's weight and body fat percentage. The participant then completed three trials of a maximal vertical jump test (only allowed a countermovement before jumping). The highest jump height achieved was the only one recorded. This procedure was repeated for the approach jump (participants were allowed to get a running start before the countermovement). The difference was measured and used as a total jump height (final reach height from jump-initial reach height). The vertical jump test series was conducted first, followed by the approach jump series.

A 160-yard shuttle run was used to assess anaerobic capacity. Two pieces of duct tape were placed 20 yards apart in an indoor facility on wooden floors and participants ran up and back a total of four times (up and back counted as one time, touch foot to the line each time). Participants were instructed to run as fast as possible. The shuttle run was recorded with a JVC camera model GCPX10U at a rate of 60 frames/second and at a resolution of 1920 x 1080p and analyzed using the Dartfish™ 7.0 software program to determine times to the nearest 1/60th of a second.

Data Analysis

A 3 x 3 mixed ANOVA was conducted to determine if a difference exists between the three training groups over the course of the study. Three separate analyses were conducted for the following three parameters: shuttle run, vertical jump, and approach jump. The following assumptions were tested: (a) independence of observations, (b) normality, and (c) sphericity. Independence of observations and normality were met. The assumption of sphericity was violated for the vertical jump and the approach jump. Thus, the Greenhouse-Geisser epsilon was used to correct degrees of freedom for these two outcomes.

Results

Table 3

Descriptive Statistics for all Participants

Group	n (total)	Average Age (yrs)	Average Height (in)	Average Weight (lbs)
Control	11	21.64	67.45	153.25
Quadmill	17	20.24	69.19	164.38
Lifting	16	21.43	68.2	159.23

The three training groups showed no significant improvement over the seven week training protocol for the shuttle run. While the results indicated a statistically significant main effect for training results, F (2, 82) = 3.961, $p < .05$, partial eta^2 = .088, but not for training group, F (2, 41) = .644, $p = .530$, partial eta^2 = .030. LSD post hoc tests revealed there was not a significant difference between any of the groups ($p < .05$). Table 4 provides descriptive statistics for the training groups for the shuttle run.

Table 4

Means and Standard Deviations for Shuttle Run Test as a Function of Training Group

		Pretest		Mid Test		Post Test	
Group	*n (total)*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Control	11	36.97	2.41	36.97	2.52	37.89	2.02
Quadmill	17	36	4.17	36.33	4.19	36.22	4.18
Lifting	16	37.29	4.36	37.51	3.84	38.01	4.39
Total	44	36.71	3.84	36.92	3.66	37.29	3.86

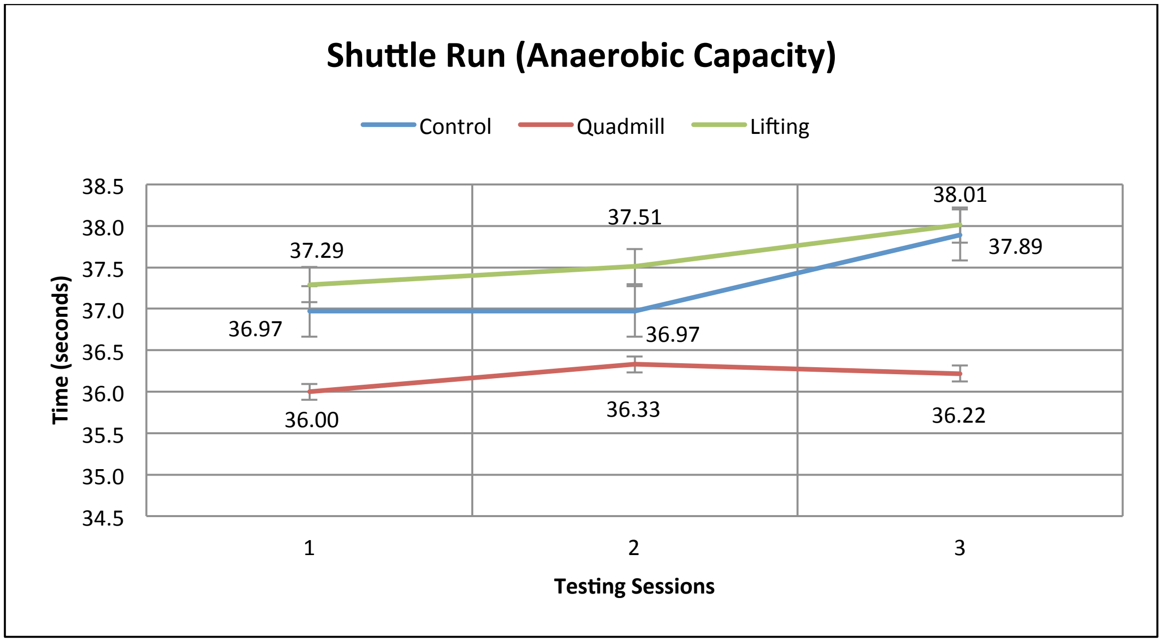

Figure 1. *Shuttle run times by group*

Over the seven week training period there was a significant improvement in vertical jump scores; a statistically significant main effect for training results, F (1.564, 64.128) = 14.886, p <.001, partial eta^2 = .266, but not for training group, F (2, 41) = .717, p = .494, partial eta^2 = .034. However, the training results main effect was qualified by a statistically significant interaction between vertical training results and training group, F (3.128, 64.128) = 5.663, p = .001, partial eta^2 = .216. LSD post hoc tests revealed that there was a significant difference between the Quadmill and control groups for the post tests. There was not a significant difference between any of the groups for the pretests, the mid tests, or between the lifting group and control group as well as the lifting group and Quadmill group (p < .05). Table 5 provides descriptive statistics for the training groups for the vertical jump.

Table 5

Means and Standard Deviations for Vertical Jump Test as a Function of Training Group

		Pretest		Mid Test		Post Test	
Group	*n (total)*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Control	11	1055.9	305.64	1055	260.74	1061.5	278.75
Quadmill	17	1142.7	336.72	1191.1	346.5	*1218.8	351.3
Lifting	16	1067.6	270.32	1097.4	269.8	1091.9	265.5
Total	44	1093.7	301.61	1123	298.6	1133.3	305.7

*p<.05

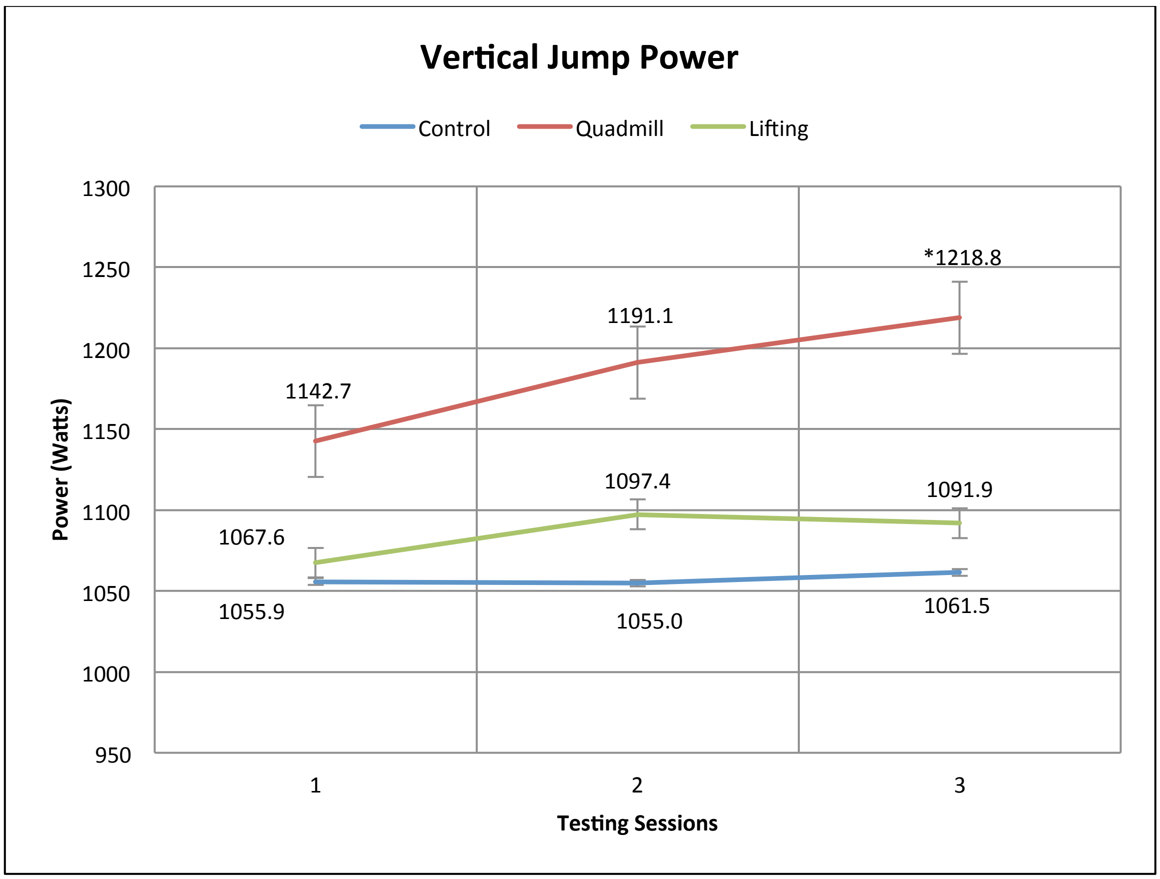

Figure 2. *Vertical jump results by group*

As seen with the vertical jump there were similar results for the approach jump; a significant main effect for training results, F (1.580, 64.767) = 9.818, p = .001, partial eta^2 = .193, but not for training group, F (2, 41) = .782, p = .464, partial eta^2 = .037. However, the training results main effect was qualified by a statistically significant interaction between approach training results and training group, F (3.159, 64.767) = 5.511, p = .002, partial eta^2 = .212. LSD post hoc tests revealed that there was a significant difference between the Quadmill and control groups for the post-tests. There was not a significant difference between any of the groups for the pre-tests, the mid-tests, or between the lifting group and control group as well as the lifting group and Quadmill group (p < .05). Table 6 provides descriptive statistics for the approach jump test.

Table 6

Means and Standard Deviations for Approach Jump Test as a Function of Training Group

		Pretest		Mid Test		Post Test	
Group	*n (total)*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Control	11	1122.9	345.94	1131.1	321.04	1122.6	307.67
Quadmill	17	1242.8	367.83	1292.5	380.2	*1315.2	400.01
Lifting	16	1177.6	298.1	1189.1	295.02	1192.4	296.79
Total	44	1189.1	333.89	1214.5	335.47	1222.4	344.33

*p<.05

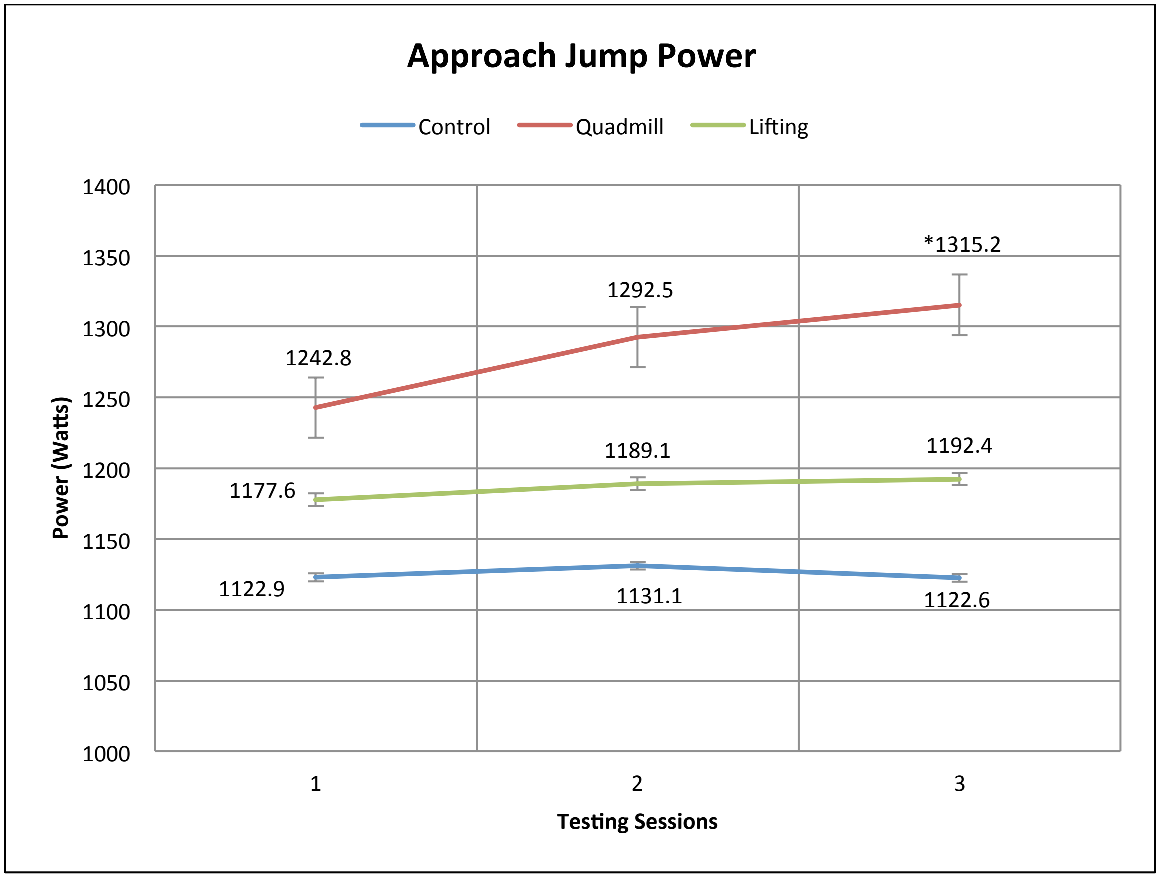

Figure 3. *Approach jump results by group*

Discussion

The results of this study showed a significant difference between the Quadmill group and the control group for the post tests of the Vertical Power and Approach Power tests, but not between any other groups or conditions. This indicates that there was a significant difference in power development over the course of the seven weeks based on training program. It can be inferred that there was a difference between the lifting group and Quadmill group based on the fact that there was a significant difference between the Quadmill and control group and no significant difference between the lifting and control group. Furthermore, the compliance for the Quadmill group was very good and the workouts required less time (about 20 minutes compared to over 30 minutes).

The positive increase in power could have been due to the fact that nearly all participants had some previous concentric training experience but no eccentric training experience (Hortobagyi & Hill et al. 1996). This may have led to an increased motor unit recruitment for participants in the Quadmill group (Sale 1987). Without measuring amount of muscle fiber tissue in some way there is no way to say for sure.

Another explanation could be that eccentric training is superior to concentric training in regards to power development. This has been supported by other studies (Riog et al. 2009, Vikne et al. 2006) and could be due in part to the fact that greater forces can be exhibited in the muscles eccentrically than concentrically at faster speeds (Hill 1970). Which would have also led to a greater development of type II muscles fibers which are used in power exercises. Future studies may consider using a muscle biopsy to investigate this further.

The lifting group was not significantly different than the control group following any of the data collections. This could be due to the majority of the participants having previous training with programs similar to the lifting program given to them and thus didn't recruit any new motor units (Sale 1987). Another explanation could be that the training sessions were not long enough to elicit a physiological change in the muscles as traditional concentric based lifting programs tend to last anywhere from 30-60 minutes (Berger 1963). The lifting group for this study was only in the gym for around 20-30 minutes, this was to try to keep the work load as even as possible between the Quadmill group and Lifting group (both between 20-30 minutes 2x a week). The Quadmill™ could have exhibited an increase in motor unit recruitment in that short amount of time due to the specificity of sport principle (Hortobagyi & Hill et al. 1996), which could explain the gains from the Quadmill group being greater than those from the lifting group.

The shuttle run did not have any significant differences in this study. The researcher believes that this was due to data collection timing. The data were collected right before school breaks and thus right around test dates. The lack of significance could be due to a lack of motivation for the shuttle run on top of the wintery conditions outside possibly affecting muscle flexibility and overall motivation to run (Altug et al. 1987).

There were a lot of confounding factors with the participants that were not controlled due to lack of time and manpower constraints. The participants were all college students with some previous resistance training. Their lifestyles were not controlled for as far as outside physical activity, nutrient consumption and timing, supplement utilization, drug consumption, or alcohol consumption. These factors could have changed how well the participants recovered between training sessions and how much improvement they could have had in their power development throughout the seven-week training protocol. Motivation could have played a very important role in all of this as well. The majority of the participants were being offered extra credit for participation and that extrinsic motivation doesn't work nearly as well as intrinsic motivation and could have affected the results.

Though there were significant differences between training groups, more investigation should be done to confirm results. In future studies the addition of a hybrid lifting/Quadmill group would be interesting to see and may elicit the best results of any group. The lengthening of training sessions would be desirable, especially for the lifting group. Traditionally three workouts per week are recommended for the whole body in typical resistance training programs (Berger, 1972). The participants in this study focused only on strengthening their legs and this may have affected the overall results.

In conclusion, the Quadmill™ training resulted in a power increase in the lower extremity. The increases in power from eccentric training support the findings of previous studies (Landin et al. 2007, Roig et al. 2009). However, these results were not immediately apparent at the midpoint of the training protocol. This could have been possibly due to motivation, length of time and duration of training, and other confounding factors as previously mentioned. The Quadmill training group had greater power development over the course of the seven weeks than did the concentric training group and control group. Therefore, it appears eccentric training is more beneficial for power development than concentric training.

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APPENDIX A

EQUIPMENT

Figure 4. *Vertec system set up (product Vertec n.d.)*

Figure 5. *Rear view of Quadmill™ (Quadmill for sale, n.d.)*

Figure 6. *Side view of Quadmill™ (Quadmill for sale, n.d.)*