A Comparative Study of Treadmill Walking/Jogging and Mini-trampoline Jogging for Metabolic Cost and Contact Forces

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ABSTRACT

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A Comparative Study of Treadmill Walking/Jogging and Mini-trampoline Jogging for Metabolic Cost and Contact Forces (67 pp.)

Director of Thesis: Sharon R. Rana

This research paper provides a comparison between the metabolic cost and contact forces between treadmill (TM) and mini-trampoline (MT) exercises. Thirteen (22.5 years ± 2.18) subjects (7 males and 6 females) performed exercises at either a set pace (126 pace per minute) or a set heart rate (65% - 85% heart rate reserve (HRR) ± 10bpm) on the TM or the MT both with and without hand and ankle weights (3.6 kg). For the metabolic cost comparison, each subject participated in 8 randomly ordered exercise sessions (TM or MT, with or without weights, at a set pace or heart rate range). Each exercise session lasted for 10 minutes, during which heart rates (HR) were recorded and the expired gases were collected to analyze the caloric expenditure and METS. Twelve (22.75 ± 2.13) subjects (7 males and 5 females) performed 4 randomly ordered trials, for the contact forces; during each an 8 second sample window was collected on the TM and MT with and without weights at a set pace (126 pace per minute). Subjects used the same pair of shoes for each trial with shoe insoles imbedded with sensory cells to collect the contact forces (Newtons) for both feet. For METS, caloric expenditure, and heart rate at an absolute load (126 pace per minute), there was a significantly ($p \leq 0.05$) higher value when exercising with hand/ankle weights than without, regardless of the piece of equipment. For the same three variables at a relative load (65-85% HRR), there was a significantly ($p \leq 0.05$) higher value on the TM than on the MT, regardless of the addition of hand/ankle weights. A significant difference ($p \leq 0.05$) was

found between the TM and MT for contact forces regardless of the addition or the absence of weights, with the MT showing higher contact forces. In conclusion, it was difficult for the subjects to attain the determined heart rate in the 65% - 85% HRR range on the MT, which could explain many of the metabolic differences. Practical applications could be that it may be easier to reach higher exercise intensity on the TM as opposed to the MT, without additional contact forces. Therefore, when performing exercises on a MT in a similar fashion to exercises on TM, one may not reach the desired intensity, and may experience additional contact forces.

Approved: ____

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CHAPTER 1: INTRODUCTION

Health promotion and disease prevention can be modified with physical activity and are closely tied with both health-related and physiological fitness (Armstrong, et al., 2006).

There have been several studies examining the positive impact of change in physical activity and fitness in relation to reducing coronary heart disease or dying prematurely from all causes (Blair, Brodney, 1999; Blair, Cheng, Holder, 2001; Blair, Kohl, Barlow, 1995; Blair, Kohl, Paffenbarger, 1989; Department of Health and Human Services [DHHS], 1991; Warburton, Nicol, Bredin, 2006a; 2006b). Warburton et al., (2006a) suggests that this has been found to be true for all age groups indicating that it is never too late to achieve the health benefits of becoming physically active, since the risk for chronic diseases starts at childhood and increases with age. The current study compared the treadmill (TM) to the mini-trampoline (MT) in terms of metabolic cost (METS, KCals, heart rate in beats per minute) and contact forces (Newtons) to determine if the MT is a piece of exercise equipment that can be a viable alternative to the 'traditional' modes of exercise like the treadmill or cycle ergometers.

To best help choose an exercise plan to increase the level of activity in daily life, or improve fitness levels, individuals might be interested in knowing how a particular piece of equipment ranks in terms of caloric expenditure. Also, the amount of exercise recommended by fitness professionals on any particular piece of equipment is based on caloric expenditure. Novice fitness enthusiasts most often choose the TM to start training programs, and athletes at varied levels of training use TMs to improve and or maintain aerobic or cardiovascular fitness. The reason may be that individuals are acclimatized to this most basic form as a necessary movement for locomotion. Armstrong et al., 2006 notes that walking may be the choice of activity for many individuals for three reasons, ready accessibility, tolerable exercise intensity and easy regulation of exercise for improving health outcomes and cardio-respiratory fitness. The authors also found that brisk walking may be an activity with enough intensity to show improvement in aerobic capacity, reduce body weight and fat stores in previously sedentary middle-aged men. The authors suggested some other variations in walking that included walking with three to six kg backpack load, and swimming pool walking for additional options in conventional walking training programs. Brisk walking (2.9 to 3.9 mph) has shown to elicit an aerobic training stimulus comparable to 50% HRR to 70% HRR max in healthy and habitual older adult walkers (> 50 years of age), (Armstrong et al., 2006). The introduction of MT may be valuable for individuals looking for variety, and motivation to continue daily exercise where specificity of exercise may not be necessary.

Impact force on joints during physical exertion is another important factor that individuals may consider in choosing a mode to use for physical activity because of its relationship to inducing and/or preventing injuries. Choice of appropriate footwear and the use of energy-absorbing materials to help dissipate shock may benefit individuals in preventing injuries from impact forces (McKenzie, Clement, & Taunton, 1985). A study by Mercer and Vance (2002) showed that by wearing spring boots there was less impact as an overall effect on joints. The spring effect was thought to help subjects gain some energy back during the latter part of the stance, thereby maintaining the same energy cost, but reducing the impact on joints. It was speculated that the MT may offer a similar benefit.

No literature was found related to direct comparison for metabolic cost or contact forces between the TM and MT. Therefore, the purpose of this study was to compare the MT and the TM directly for metabolic cost and to determine which piece of equipment had a higher caloric expenditure at both an absolute and relative intensity. Also, a direct comparison was designed to compare the contact forces on the two pieces of equipment. Use of hand and ankle weights was included for comparison of the metabolic and contact force trials on both pieces of equipment and under both intensity categories. Subjects were drawn from a pool of volunteers of both genders between 18-26 years of age, were untrained – did not participate in club or varsity sports, and with moderate to high activity levels. A health history questionnaire was used to learn about the subjects' apparent health status. Many people may be aware of existence of MT as it has been in the marketplace for sometime, but none of the subjects had any familiarity with its use, as confirmed verbally.

Research Questions and Significance

The first question addressed was which piece of equipment has a higher metabolic cost: the MT or the TM? This information could be used to assist potential users determine which exercise mode might be the most beneficial in increasing caloric expenditure.

The second question addressed was which piece of equipment has lower contact forces: the MT or the TM? This information could be used to assist potential users to determine which exercise mode might provide the least joint stress (impact).

Hypotheses

There were two intensities under which the comparison between the TM and MT was made; one at a 65% - 85% HRR (relative intensity) and the other at 126 pace per minute (absolute intensity). The subjects were also tested with the addition of hand and ankle weights on each piece of equipment for both intensities.

Metabolic Expenditure

H1: Trials on the MT would have higher metabolic expenditure than the TM at 126 pace per minute.

H2: Trials on the MT would have higher metabolic expenditure than the TM at 65% - 85% HRR.

Contact Forces

H3: Trials on MT would have lower contact force than the TM at 126 pace per minute.

Although the main aim of this study was not to compare the same piece of equipment, this comparison was attempted for contact forces. It was hypothesized as follows:

H4: Trials on the MT with weights would have higher contact forces than the MT without weights at 126 pace per minute.

H5: Trials on the TM with weights would have higher contact forces than the TM without weights at 126 pace per minute.

Definition of Terms

Apparent Health Status: The status of health as perceived from the answers by the subjects to the health history questionnaire (Armstrong et al., 2006).

Contact Forces: a force between two objects (or an object and a surface) that come in contact with one other (Dirkx, 2001).

Heart Rate Reserve: difference between resting heart rate and heart rate during maximal exercise (Armstrong et al., 2006).

MET is defined as the ratio of work metabolic rate to a standard metabolic rate of 1.0 (4.184 kJ)*(1/kg)*(1/h), one MET is considered a resting metabolic rate obtained during quiet sitting (Armstrong et al., 2006).

Metabolism: The chemical processes occurring within a living cell or organism that are necessary for the maintenance of life. In metabolism some substances are broken down to yield energy for vital processes while other substances, necessary for life, are synthesized (The American Heritage Dictionary, 2006).

Mini-trampoline: a strong, taut sheet, usually of canvas, of around 1-2 feet in diameter attached with springs to a metal frame (Dirkx, 2001).

Modality: a form of application or employment of a therapeutic agent or regimen Dirkx, 2001).

Physical Activity: any body movement produced by muscles that result in energy expenditure (Armstrong et al., 2006).

Physical Fitness: a set of attributes relating to one's ability to perform physical activity. Health related physical fitness refers to components of physical fitness (most commonly, aerobic fitness, body composition, abdominal muscular strength and endurance, and lower back and hamstring flexibility) that are associated with some aspect of overall good health or disease prevention (Armstrong et al., 2006).

Treadmill: an exercise device consisting of a continuous moving belt on which a person can walk or jog while remaining in one place (Dirkx, 2001).

CHAPTER 2: REVIEW OF LITERATURE

Overview

This chapter is organized around areas that are pertinent to the methodology utilized in the current study. The areas include metabolic costs of treadmill walking, metabolic costs of exercise on a mini-trampoline, and contact forces of walking/jogging.

The Metabolic Costs of Treadmill Walking

The metabolic costs of exercising on a TM under various conditions and for different variables have been studied in the past (Bunc and Dlouha, 1997; Epstein, Rosenblum, Bursteinand, Sawka, 1988; Graves, Martin, Miltenberger, and Pollock, 1988; Keren, Epstein, Magazanik, and Sohar, 1981; Peterson, Palmer, and Laubach, 2004; Putthoff, Darter, Neilsen, and Yack, 2006. Peterson et al. (2004) conducted a comparative study of caloric expenditure between intermittent and continuous walking bouts. They compared a 30 min continuous bout to three sets of 10 min intermittent bouts, of moderate intensity. Their results showed that three separate 10 min bouts were equivalent in caloric expenditure to the continuous bouts of 30 min. Based on these results, the current study utilized 10 minutes of exercise duration on the TM for a total of four separate bouts with an 8 min rest in between each exercise bout.

Putthoff et al. (2006) studied the effects of weighted vests on metabolic costs and ground reaction forces during TM walking. The authors concluded that using additional weight increased metabolic expenditure (Epstein et al., 1988; Graves, et al., 1988) relative exercise intensity (Epstein et al.), and loaded the joints more than walking without any additional weight.

Selection of different intensities while walking or running exercises on a TM can affect the metabolic cost. The intensity usually correlates linearly with the heart rate. The higher the intensity, the higher the heart rate, and the greater the number of calories expended. (Bhattacharya, McCutcheon, and Greenleaf, 1980; Moyna et al., 2001). Although it is generally assumed that there is a linear relationship between work rate and metabolic rate, comparison specifically done between the two pieces of equipment may help determine if a piece of equipment helps expend more calories as compared to another at particular given intensity. This information may be used to design specific protocol for exercises on each of the two pieces of equipment in future studies.

The Metabolic Costs of Exercises on a Mini-trampoline

There has been limited research found on the energy cost of exercises on a MT as compared with other aerobic activities such as cycling, aerobic step dance, and dance (Gerberich, Leon, McNally, Serfass, and Edin, 1990; Katch, Villanacci, & Sady, 1981; Smith and Bishop, 1988). Katch et al., (1981) conducted a study examining the energy cost of exercising on a MT (rebound-running). It was found that compared to pre-training results, an improvement in the maximal oxygen consumption capacity at different intensities with the use of additional weights and different pace was observed (Katch et al., 1981; Smith and Bishop, 1988). Katch et al. (1981) found a 5.1 MET load was achieved on the MT, which lead them to conclude that the MT was a ‘moderate intensity’ category of physical activity. This was comparable to other activities of approximately the same MET level as walk-jog at 4-4.5 mph, bicycle at 8 mph, moderate to vigorous dancing, fishing, golf, recreational volleyball, table tennis, and recreational sailing. The heart rate response only showed moderate stress for subjects in the age range. The subjects were not as stressed on the MT at their self-chosen pace of 54-68 pace per minute while maintaining the 'normal' rebound run effect, as they would have otherwise felt with jogging for 10 min. (Katch et al., 1981). This helped the investigators of the current study to determine an appropriate amount of time for jogging on the MT, as was determined for walking/jogging on the TM. Katch et al. (1981), concluded that the total Kcal expenditure for rebound running is roughly 0.0864 Kcal* kg-1*min-1. They presented an equation with which the Kcal expenditure could be more accurately used to predict from body mass (Kg) as the following equation:

$\gamma' = 0.1141\ X - 1.8088$, where X = body weight

Studies by Evans et al., 1984; Gerberich et al., 1983; Tomassoni et al., 1985; White, 1980 (as cited by Smith and Bishop, 1988) to see if exercising on a MT was sufficient to achieve cardio-respiratory fitness. They reviewed different articles on protocols, methodological differences on measurements of energy expenditure, and results. Smith and Bishop (1988) emphasized the need for additional research on the cardio-respiratory benefits of exercising on MT. They also suggested that most studies were training studies, as none were based on a short duration of exercise, which had resulted in improvement in the maximal oxygen consumption capacity on the MT (Smith and Bishop, 1988). However, no study presented a direct comparison between exercising on the MT and any other aerobic exercise.

Studies by Evans et al., 1984; Gerberich et al., 1983; Tomassoni et al., 1985; White, 1980 (as cited by Smith and Bishop, 1988) pointed out several factors affecting the caloric expenditure on the MT including stiffness of the running/rebounding surface, the step height, and step frequency. Other factors affecting the caloric expenditure included number of weeks of training, duration of a single session, and number of sessions being conducted per week through the training duration. Intensity ranged from a set pace to a certain percent of heart rate maximum. The choice of modes of equipment, training specificity, and the statistical designs for result analyses, specific to each methodology, may have influenced the results as shown in several studies by Evans et al., 1984; Gerberich et al., 1983; Tomassoni et al., 1985; White, 1980 (as cited by Smith and Bishop, 1988; see also Gerberich et al., 1990). Smith and Bishop thought, since the pattern of movement can affect the energy cost, it may be an inappropriate comparison between the two pieces of equipment. Gerberich et al. (1990) reported that different styles of jogging and bouncing on the MT when compared with graded exercise protocols affected the energy expenditure substantially.

Smith, Bishop, Ellis, Conerly, and Mansfield, (1995) investigated the effects of hand held weights during rebounding exercise on intensity and concluded that adding hand held weights helped bring a low intensity exercise on a MT to a moderate intensity. Their study compared different weights with different heights to which the weights were pumped. A pumping height of 91 cm resulted in higher energy cost than a 61 cm pumping height, regardless of the amount of weight. When using the pumping height of 91 cm, 1.36 kg resulted in greater mean energy expenditure than using 0.45 kg. A weight of 1.36 kg also resulted in great mean heart rate than either 0.45 kg or 0.91 kg weights. When pumping 0.45 kg to a height of 61 cm added to rebounding, a substantial increase in VO2 (26% increase) and HR (12% increase) was noted. This according to the authors was roughly comparable to a 10 min per mile jog. A significant increase in VO_2 and HR was also noted when the weight was increased to 1.36 from 0.91 kg. The improvement was all in comparison to rebounding without any weights or without raising their hands in the air to a certain height. They suggested that higher amount of weights may have to be used for subjects with high levels of fitness, who may require higher intensity training (Smith et al., 1995).

Studies on Contact or Ground Reaction Forces

Ground reaction forces have been studied for exercising on a treadmill, but few studies have measured contact forces on a TM using portable pressure measurement systems, and no one has compared contact forces on a MT to those on a TM. Different literature included effects of different footwear on running related injuries, running on different surfaces, effect of shock absorption with footwear and surface stiffness, effect of additional weights on ground reaction forces and to account for differences in ground reaction forces while walking/jogging/ running on a TM.

Impact forces on joints have thought to be related to injuries with running (Clement, Taunton, 1981; McKenzie et al., 1985). Dixon, Collop and Batt (2000), showed that absorption of impact forces varied between surfaces with different stiffness (Dura, Hoyos, Lozano, and Martinez, 1999; Feehery, 1986; Ferris, Louie, and Farley, 1998). They found that injuries related to running couldn’t be directly based on differences in surface stiffness because individuals tend to adapt to the surface and maintain the biomechanical requirements of the movement (Feehery, 1986; Kerdok, Biewener, McMahon, Weyand, and Herr, 2001). Nigg, (2001) studied the role of impact and foot pronation, related to running injuries. He explained that while going to a softer surface from a harder surface, individuals increased leg stiffness to be able to maintain a running pattern on the softer surface. He presented a similar idea showing that there existed a neuro-muscular adaptation of short duration, before each new stance. Nigg stated, “high-loading and high-impact forces cannot be directly held responsible for running related injuries” (Nigg, 2001, p. 2).

A study on plantar forces during running on different surfaces by Tillman, Fiolkowski, Bauer and Reisinger (2002) showed no significant difference for the variables of shoe reaction force, contact time or impulse. Participants, who ran at the same velocity on each of these surfaces, were not exposing themselves to any additional risk on harder surfaces as a result of joint impact. Instead, injury may be because of anatomical internal mechanisms of compensations (Dura et al., (1999); Feehery, 1986; Ferris et al., (1998)). A study by Dura et al., reported some important findings that surfaces with higher shock absorbing capacity do not always help reduce risk of injuries, when compared to activities causing joint impact on harder surfaces. Since, differences in stiffness of surfaces have not been attributed directly to changes in contact forces and also adaptation of human subjects to changes in terrain during locomotion has been associated with internal anatomical, biomechanical, and neurological adaptations, a comparison between the two pieces of equipment for contact forces may be valid (Dixon et al., 2000; Dura et al., 1999; Feehery, 1986; Keller et al., 1996; Nigg, 2001; Nyska, Linge, McCabe, Klenerman, 1997).

Conclusion

No research was found that made a direct comparison between TM and MT on metabolic cost. The current study attempted to see which piece of equipment had higher metabolic expenditure. Also, no supporting literature for contact force measurements done independently on MT, or comparisons between any other pieces of equipment, especially the

TM, were found. Studies involving ground reaction forces on TM were done using different systems and covered different aspects of measurements. Comparisons were limited to different surfaces, with the addition of weights on these surfaces, and for different speeds of walking/jogging/running, but none with direct comparison of these two pieces of equipment.

CHAPTER 3: METHODS

This study was conducted in the exercise physiology laboratory at, Ohio University, Ohio, Grover Center E228.

The following schedule was used for collecting the data:

Day 1: Orientation / Familiarization Session (45 min)

Day 2: Four randomly assigned metabolic costs trials (90 min) followed by a 24 hr break/rest.

Day 3: Four randomly assigned metabolic costs trials (90 min)

Day 4: Four randomly assigned contact force trials (20 min)

Orientation Session

Volunteers, in an orientation session, were informed of the specific requirements of the study and completed an Institutional Review Board see Appendix A) approved consent form (see Appendix B). The total number of subjects who participated for the entire study was 13, men (n = 7) and women (n = 6) between the ages of 18 and 30 years and were apparently healthy. However, only 12 subjects participated in the data collection phase for the contact forces (men = 7, women = 5). Trials numbered from one to eight were randomized for each subject. This eight digit random number was also each subject's unique identification code. Subjects were given a handout with a thorough explanation of the study, equipment, and were informed of the specific requirements for participation during the study. The schedule of the study was explained to them pictorially (see Figure 1 and Figure 2). Contact force data and metabolic expenditure data were to be recorded at the same time;

however, a delay in receipt of the contact force measurement equipment necessitated an additional day of data collection.

All subjects completed a health history questionnaire (see Appendix C), to check the health status of subjects. This was done to support the apparently healthy status of all the participants and to minimize the risk of any possible injury.

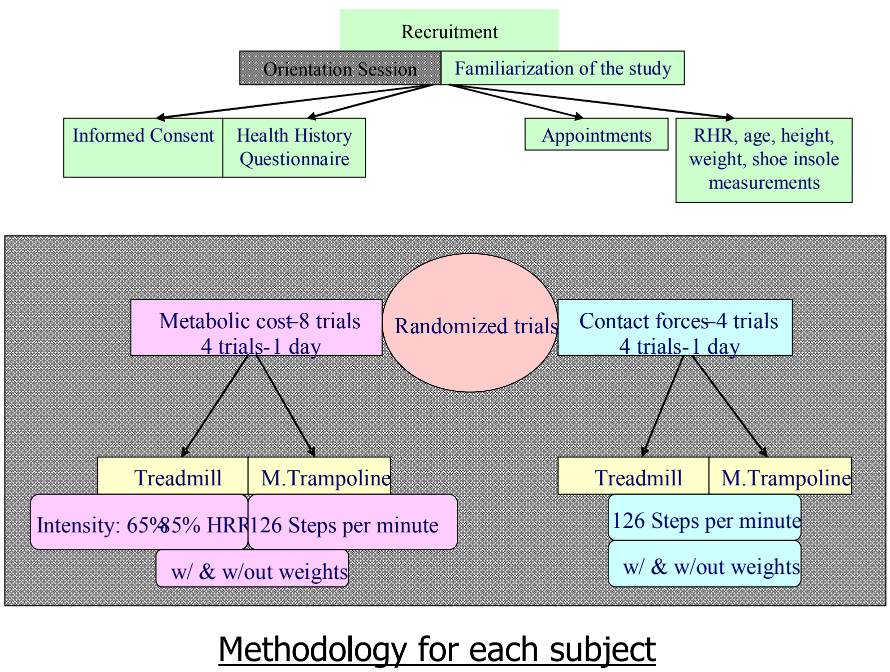

Figure 1. Methodology for each subject. For the metabolic expenditure trials, four trials were performed per day over 2 days.

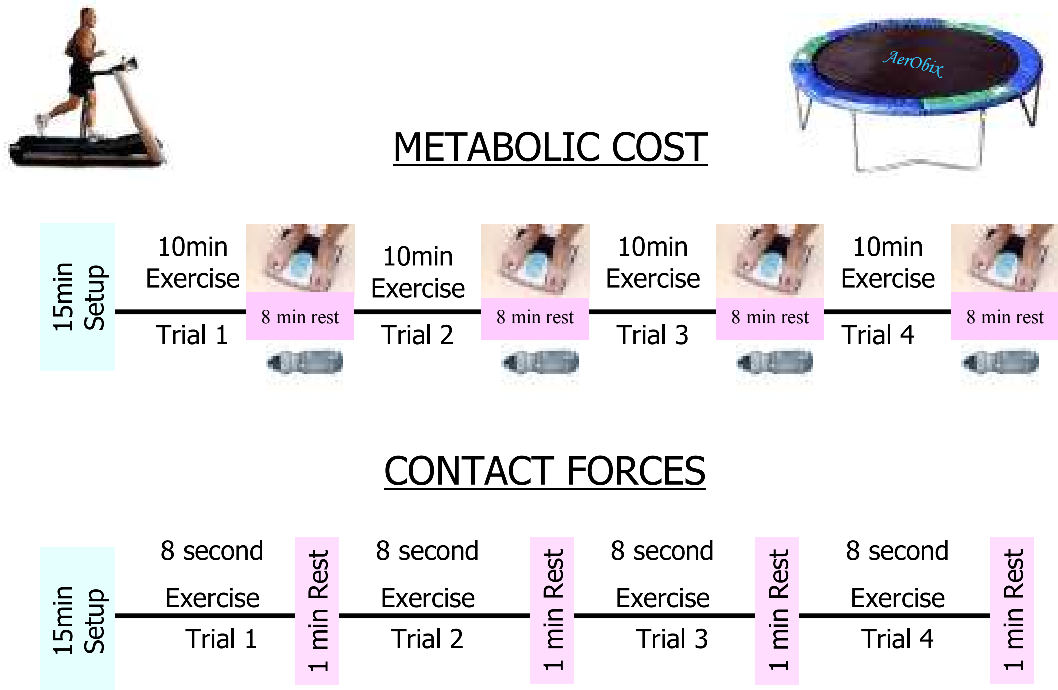

Figure 2. Data collection process for metabolic expenditure and contact forces. For the metabolic expenditure trials, four trials were performed per day over 2 days.

Each subject's mass, with shoes, was measured on the same calibrated standardized digital scale (SECA- NA East, MD, USA) throughout the study. They were asked to maintain a regular diet with approximately the same amount of food at each meal and were told not to eat at least 2 hours prior to the trials. They were requested to avoid any alcohol consumption, or excessive use of caffeine, prior to the trials. This request was made to avoid the effects of alcohol consumption (dehydration), any effects on heart rate and for the subjects' safety while using the equipment. To avoid exertion and fatigue, participants were directed not to participate in any physical exercise on the day before the trials. The subjects were directed to wear the same shoes for each trial to maintain consistent shock absorption patterns and weight distribution. The shoe insoles (Tekscan, Inc. Boston, MA) were traced and cut according to instructions, by the same investigator. Subjects' heights were also recorded during the orientation session, using a stadiometer (Invicta Plastics Ltd., Leicester, England). The resting heart rate for each subject was taken in the early morning, during the orientation session, and recorded after 15 minutes of rest in a supine position with low light and in a quiet environment. This was to avoid external factors that might have altered the true resting heart rate.

Metabolic Expenditure

The conditions tested for metabolic costs were:

TM with hand/ankle weights at a set pace of 126 pace per minute

TM without hand/ankle weights at a set pace of 126 pace per minute

MT with hand/ankle weights at a set pace of 126 pace per minute

MT without hand/ankle weights at a set pace of 126 pace per minute

TM with hand/ankle weights at a target heart rate range of 65% - 85% HRR (heart rate reserve)

TM without hand/ankle weights at a target heart rate range of 65% - 85% HRR

MT with hand/ankle weights at a target heart rate range of 65% - 85% HRR

MT without hand/ankle weights at a target heart rate range of 65% - 85% HRR

The medical stress TM (TrackMaster TMX425C, Newton, KS, U.S.A.) available in the exercise physiology laboratory was used for this study. It supported weight of up to 400lbs., with a large running surface, and had a speed capacity of 0.5 – 12 miles per hour (mph). There were safety rails for the subjects to use at their disposal if they encountered any discomfort during the trials and wished to stop. The display console showed the pace in miles per hour, which was used to record, the subject's speed during the trials.

The MT (Airobix, Inc.) used in this study was a 40 inch steel frame with six steel legs that can support up to 300 pounds. Easily maneuverable at a weight of 16 pounds, it featured 36 super-sized springs to deaden the surface. It was one foot in height. The potential of falling off was very low because of its low height and large diameter surface area.

Absolute (L/min) and relative (ml/kg/min)VO_2, METS, and cumulative caloric expenditure were recorded with a metabolic cart (ParvoMedics, Inc., Sandy, UT, U.S.A.) during each trial. The metabolic cart was calibrated following every four uses. Heart rates were measured during each trial using Polar A1 monitors (Polar Electro, Inc., NY, U.S.A.) and with a built-in monitor linked to the metabolic cart; heart rate was recorded throughout the exercise time. The subjects were allowed up to two practice trials of 30 seconds on each piece of equipment before starting data collection. This was to familiarize them, and yet avoid any learning effects. Familiarization helped the subjects be comfortable on the equipment and helped minimize errors like lack of consistency in pace, or difficulty in maintaining a normal pattern during jogging or running by the participants during the testing period.

For trials using a set pace, a metronome was set at 126 pace per minute and subjects were instructed to have the foot contact the surface with each beat. For those trials using a target heart rate, the heart rate reserve method was utilized (Armstrong et al., 2006) (see Appendix D) and subjects were asked to keep their heart rate between 65% and 85% of their respective HRR (± 10 bpm). The 10 bpm leeway was given since estimated maximal heart rates (220 – age) were used to calculate the heart rate range. For the trials with a target range, once the subject reached a heart rate within the target heart rate range, a metronome was set to match the subject's pace on the equipment. This helped the subjects maintain a consistent pace throughout the exercise time. The trials with hand and ankle weights on the two pieces of equipment involved using 2 pound hand and ankle weights for each limb (a total of 8 extra lbs). Each trial lasted for 10 minutes timed with a stopwatch (Accusplit Pro-Survivor, San Jose, CA). The subjects had 3 to 5 minutes to reach a steady state, and data collected over the remaining 5 minutes was averaged and reported. There was an 8 minute rest period between trials. The rest time allowed the subjects to come down to a resting heart rate, and to prepare for the next trial.

During the resting time, the subject's weight was immediately measured. If there was a loss of 1/10th of a kilogram, the subject was provided with 100 ml of drinking water, measured with a calibrated measuring cup, to replace the amount of fluid lost and to prevent the effect of cardiac drift over the 40 minutes of exercise. The subjects were asked to avoid urinating during the resting time to avoid additional loss of fluid, not resulting from exercise. In a case where the subject had to urinate, weight was recorded and the fluid was replaced equal to the amount of 100 ml of water for every 1/10th of a kilogram loss of weight.

Contact Forces

This study was also designed to determine the difference in contact forces between the treadmill and the mini-trampoline under two conditions; with and without hand/ankle weights.

The following conditions were tested for contact forces; trials were randomized.

TM with hand/ankle weights at a pace of 126 pace per minute

TM without hand/ankle weights at a pace of 126 pace per minute

MT with hand/ankle weights at a pace of 126 pace per minute

MT without hand/ankle weights at a pace of 126 pace per minute

The contact force data was collected using software and hardware (F-Scan mobile) manufactured by Tekscan, Inc. (Boston, MA). The F-Scan® Mobile was used to measure foot plantar forces bilaterally. The insole sensors in the shoes were extremely thin (0.15mm), and crease resistant to last longer during the data collection. Each subject's right shoe sole was drawn by tracing his or her shoe insole on white clear drawing paper. The insole sensor sheets were precisely cut for right side, and inverted or flipped for measuring and cutting for the left side from the shoe insole drawing for each subject. The same set of insole sensor sheet was used for each subject throughout the data collection for contact forces. The sensory cell contained high-resolution sensory cells (4 sensors/cm2) that scanned at a rate of 500 Hertz (see Figure 3 and Figure 4). This lightweight telemetry system recorded data instantaneously to a collective receiver unit and battery pack strapped to each subject's waist, which in turn was connected to the F-Scan cuffs on the ankles, and the F-Scan shoe insoles.

The wireless setup helped avoid hindrance to the subjects during the data collection (Figure 5).

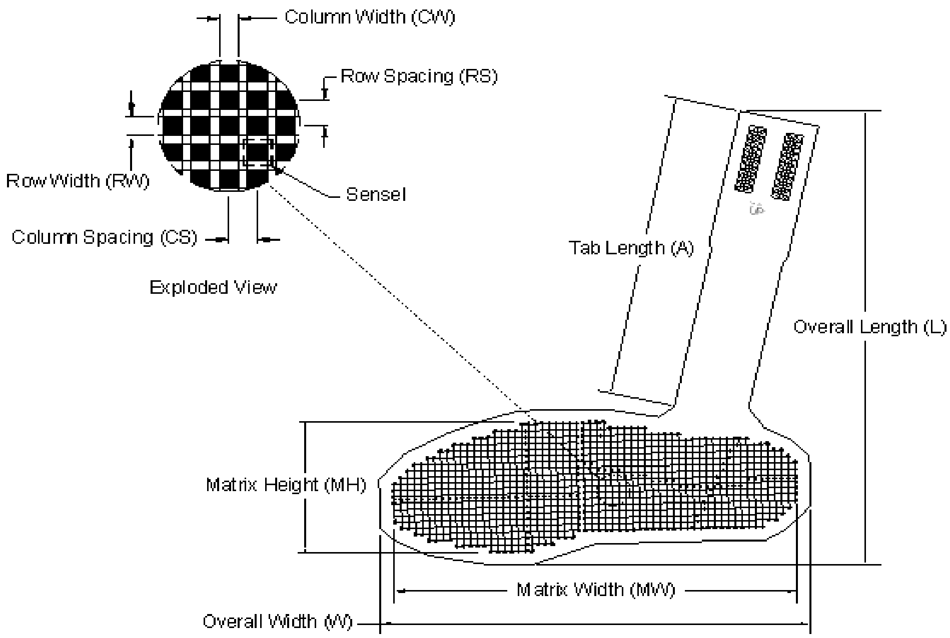

Figure 3. Sensory shoe insole. Source: Tekscan, Inc., from the website: www.tekscan.com

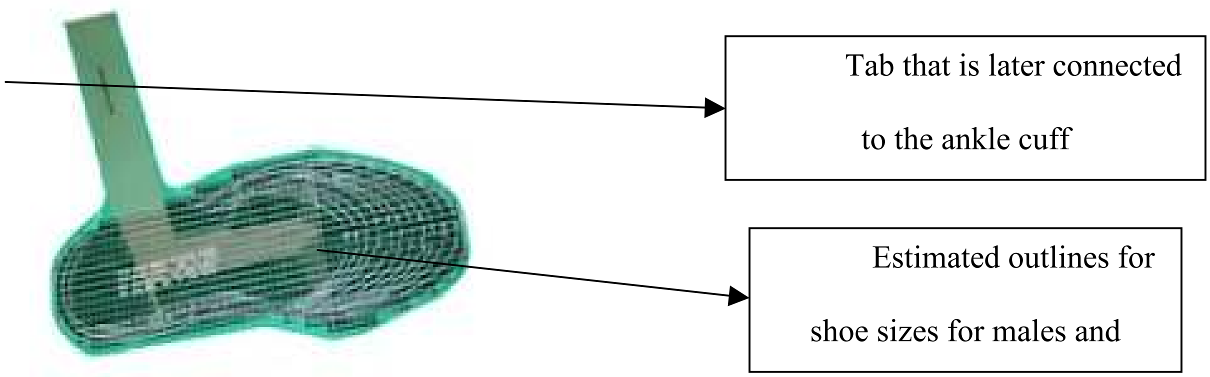

Figure 4. Sensory shoe insole. Source: Tekscan, Inc., from the website: www.tekscan.com

Figure 5. Sample of the assembled units of the F-scan mobile. Source Tekscan, Inc. from the website: www.tekscan.com

For each trial, the F-Scan system was calibrated according to the manufacturer's instruction. Subjects were free to start recording when they were ready; each recording lasted for 8 seconds. A minute of rest followed each trial. The recorded data and movies were stored as subject files on a computer and later used for data analyses. Data was processed with software provided by Tekscan. A feature, called the Multi-Stance averaging (see Figure 6) was used. A total of ten stances were recorded over the period of 8 seconds. Eight stances, excluding the first and the last steps of the total 10 steps were averaged. The force present over the entire foot area for each stance was recorded in Newtons.

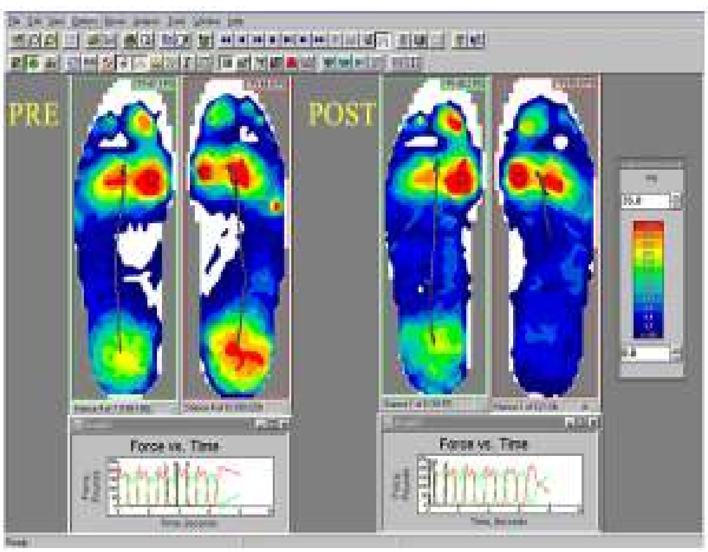

Figure 6. Sample of a graphic display of the recorded data. Source: Tekscan, Inc from the website: www.tekscan.com

Statistical Data Processing

SPSS version 14.0 (SPSS, Inc. for Windows XP (Microsoft, Inc.)) was used to analyze all raw data. The level of statistical significance was $\alpha < 0.05$. Six 2x2 (equipment x weights) repeated measures ANOVAs were performed for METS, cumulative Calories, and heart rate for both specific intensities. A 2x2 (equipment x weights) repeated measures ANOVA was used to analyze the four contact force trials. If, for any of the 2x2 repeated measures ANOVA analyses, a significant interaction was found, the model was broken down by using paired t-tests. If the interaction was not significant, the main effects were analyzed. In this case, no post hoc test was necessary since there were only two conditions in each factor.

CHAPTER 4: RESULTS

The Metabolic Expenditure

Mean values (*M*) ± standard deviations (*SD*) for the descriptive data of subjects including age, height and weight is presented in Table 1. The *M* and *SD* for other variables for all subjects include the METS, heart rate and cumulative Calories for each exercise bout are shown in subsequent tables.

Table 1

Subject Characteristics: Age, Height, Weight, Resting Heart Rate, 65% - 85% HRR

N = 13	Range	*M* ± *SD*
Age (years)	20.000 - 27.000	22.500 ± 2.180
Height (cms)	161.500 - 190.500	175.800 ± 8.010
Mass (Kg)	60.000 - 84.800	71.120 ± 8.010
Resting Heart Rate (bpm)	46.000 - 68.000	55.610 ± 6.940
65% HRR ± 10 bpm	144.000 - 153.000	147.460 ± 2.810
85% HRR ± 10 bpm	172.000 - 180.000	175.840 ± 2.190

METS

METS were calculated to present the data in a more understandable manner. It represents how hard a subject had to work, and what the oxygen consumption was, as compared to the resting values of oxygen consumption (Armstrong et al., 2006). The statistical results for absolute and relative oxygen consumption yielded exactly the same output as the METS.

Absolute Workload (126 Pace per Minute)

A 2x2 (equipment x weights) repeated measures ANOVA was performed for METS at the absolute workload of 126 pace per minute (see Table 2). The interaction between equipment and weights was not significant (p = 0.588). The main effect for equipment was also not significant (p = 0.602) but the main effect for weights was significant (p = 0.023). Therefore, regardless of the piece of equipment, METS was higher during exercise performed with weights (marginal mean 5.126 ± 0.177 METS) than without (marginal mean 4.832 ± 0.150 METS) at an absolute workload.

Table 2

Mean and Standard Deviation for METS at an Absolute Workload (126 Pace per Minute) Including Marginal Means (Marginal Means Reported M ± Standard Error(SE))

	Weights	No Weights	Marginal Means
TM	5.297 ± 0.468	4.795 ± 0.428	5.046 ± 0.113
MT	4.956 ± 1.026	4.870 ± 0.942	4.913 ± 0.256
Marginal Means	5.126 ± 0.177*	4.832 ± 0.150*	

Note. Marginal means differ at *$p<0.05$

Relative Workload (65-85% Heart Rate Reserve)

A 2x2 (equipment x weights) repeated measures ANOVA was performed for METS at the relative workload of 65-85% HRR (see Table 3). The interaction between equipment and weights was not significant ($p = 0.116$). The main effect for equipment was significant ($p < 0.001$), but the main effect for weights was not ($p = 0.618$). Therefore, there was a significant difference, regardless of the addition of hand and ankle weights, METS was higher for exercise performed on the TM (marginal mean 8.880 ± 0.435 METS) than on the MT (marginal mean 7.197 ± 0.294 METS) at a relative workload.

Table 3

Mean and Standard Deviation for METS at a Relative Workload (65-85% Heart Rate Reserve) Including Marginal Means (Marginal Means Reported M ± SE)

	Weights	No Weights	Marginal Means
TM	9.018 ± 1.601	8.743 ± 1.625	8.880 ± 0.435*
MT	6.933 ± 0.946	7.461 ± 1.610	7.197 ± 0.294*
Marginal Means	7.975 ± 0.295	8.102 ± 0.404	

Note. Marginal means differ at *$p<0.05$

Caloric Expenditure

Absolute Workload (126 Pace per Minute)

A 2x2 (equipment x weights) repeated measures ANOVA was performed for Caloric expenditure at the absolute workload of 126 pace per minute (see Table 4.). The interaction between equipment and weights was not significant ($p = 0.992$). The main effect for equipment was also not significant ($p = 0.763$), but the main effect for weights was significant ($p = 0.001$). Therefore, regardless of the piece of equipment, Caloric expenditure was higher during exercise performed with weights (marginal mean 36.039 ± 1.703 Kcals) than without (marginal mean 32.706 ± 1.406) at an absolute workload.

Table 4

Mean and Standard Deviation for Caloric Expenditure (Kcals) at an Absolute Workload (126 Pace per Minute) Including Marginal Means (Marginal Means Reported M ± SE)

	Weights	No Weights	Marginal Means
TM	35.733 ± 5.110	32.390 ± 4.746	34.061 ± 1.318
MT	36.346 ± 9.319	33.021 ± 7.394	34.683 ± 2.205
Marginal Means	36.039 ± 1.703*	32.706 ± 1.406*	

Note. Marginal means differ at *$p<0.05$

Relative Workload (65-85% Heart Rate Reserve)

A 2x2 (equipment x weights) repeated measures ANOVA was performed for Caloric expenditure at the relative workload of 65-85% HRR (see Table 5). The interaction between equipment and weights was not significant ($p = 0.090$). The main effect for equipment was significant ($p < 0.001$), but the main effect for weights was not ($p = 0.652$). Therefore, regardless of the addition of hand and ankle weights, Caloric expenditure was higher for exercise performed on the TM (marginal mean 61.741 ± 3.808 Kcals) than on the MT (marginal mean 48.672 ± 2.292 Kcals) at a relative workload.

Table 5

Mean and Standard Deviation for Caloric Expenditure (Kcals) at a Relative Workload (65-85% Heart Rate Reserve) Including Marginal Means (Marginal Means Reported M ± SE)

	Weights	No Weights	Marginal Means
TM	62.974 ± 14.369	60.507 ± 13.562	61.741 ± 3.808*
MT	46.768 ± 7.442	50.576 ± 11.518	48.672 ± 2.292*
Marginal Means	54.871 ± 2.728	55.542 ± 3.146	

Note. Marginal means differ at *p<0.05

Heart Rate

Absolute Workload (126 Pace per Minute)

A 2x2 (equipment x weights) repeated measures ANOVA was performed for heart rate at the absolute workload of 126 pace per minute (see Table 6). The interaction between equipment and weights was not significant (p = 0.378). The main effect for equipment was also not significant (p = 0.804), but the main effect for weights was significant (p = 0.045). Therefore, regardless of the piece of equipment, heart rate was higher for exercise performed with weights (marginal mean 108.410 ± 3.744 bpm) than without (marginal mean 105.306 ± 3.741 bpm) at an absolute workload.

Table 6

Mean and Standard Deviation for Heart Rate (bpm) at an Absolute Workload (126 Pace per Minute) Including Marginal Means (Marginal Means Reported as M ± SE)

	Weights	No Weights	Marginal Means
TM	108.705 ± 11.764	104.051 ± 14.998	106.378 ± 3.579
MT	108.115 ± 17.613	106.561 ± 16.680	107.338 ± 4.626
Marginal Mean	108.410 ± 3.744*	105.306 ± 3.741*	

Note. Marginal means differ at *$p<0.05$

Relative Workload (65-85% Heart Rate Reserve)

A 2x2 (equipment x weights) repeated measures ANOVA was performed for heart rate at the relative workload of 65-85% HRR (see Table 7). The interaction between equipment and weights was not significant ($p = 0.590$). The main effect for equipment was significant ($p = 0.009$), but the main effect for weights was not ($p = 0.066$). Therefore, regardless of the addition of hand and ankle weights, heart rate was higher for exercise performed on the TM (marginal mean 146.542 ± 1.569 bpm) than on the MT (marginal mean 137.007 ± 3.984 bpm) at a relative workload.

Table 7

Mean and Standard Deviation for Heart Rate (bpm) at a Relative Workload (65-85% Heart Rate Reserve) Including Marginal Means (Marginal Means Reported as M ± SE)

	Weights	No Weights	Marginal Means
TM	148.731 ± 5.902	144.353 ± 5.987	146.542 ± 1.569*
MT	140.823 ± 10.228	133.191 ± 22.996	137.007 ± 3.984*
Marginal Means	144.777 ± 2.032	138.772 ± 3.737	

Note. Marginal means differ at *$p<0.05$

Contact Forces

The same subjects, who were involved in the metabolic cost measure, participated for this portion of data collection. One female subject was unable to participate in this part of the study because of a personal reason making $N = 12$. Contact force data was analyzed using a 2x2 (equipment x weights) repeated measure ANOVA (see Table 8). The two-way interaction of equipment x weight was not significant ($p = 0.056$). However, the main effect for equipment was significant ($p < 0.001$), while the main effect for weight was not ($p = 0.071$). Therefore, regardless of the addition of hand and ankle weights, the contact force was greater on the mini-trampoline (marginal mean 1515.752 ± 106.108 N) than the treadmill (marginal mean 983.020 ± 54.706) at an absolute workload of 126 pace per minute.

Table 8

Mean and Standard Deviation for Contact Forces (Newtons) including Marginal Means (Marginal Means Reported as M ± SE)

	Weights	No Weights	Marginal Means
TM	984.679 ± 193.919	981.360 ± 186.465	983.020 ±54.706*
MT	1565.186 ± 374.603	1466.318 ± 378.369	1515.752 ± 106.108*
Marginal Means	1274.933 ± 74.129	1223.839 ± 69.798	

Note. Marginal means differ at $*p<0.05$

CHAPTER 5: DISCUSSION

Metabolic Expenditure

This study investigated the metabolic expenditure on two pieces of equipment, the MT and the TM, with and without the addition of hand and ankle weights, at both an absolute and relative intensity. The first two hypotheses of this study stated that the MT would have a higher metabolic expenditure than the TM at both intensities. The subjects were encouraged to maintain a normal "running or jogging" pattern that was natural to each individual, on both pieces of equipment. They were not required to adopt a particular pattern of running or jogging on the equipment (Gerberich et al., 1990; Smith et al., 1995). Exercising either jogging or bouncing on a MT, in one place, influences the metabolic output as shown in a study by Gerberich et al.. Similarity between walking and jogging may be seen as a common form of human locomotion. However, walking or jogging on the TM would allow a subject to move forward, whereas the movement on the MT occurred in one place without forward propulsion. TM movement is horizontally propulsive in nature, and the pattern of jogging on the MT is primarily vertically oriented. Raising the center of gravity usually costs more metabolically, as seen with activities like treadmill walking with a graded incline, or activities similar to hiking (S. Bullard, personal communication, January 22, 2007). One may argue that jogging on a MT seems more unstable than jogging on a TM and therefore exercising on MT should result in higher caloric expenditure, thus the reason for these hypotheses.

Metabolic Cost at the Absolute Workload

When testing the difference between the TM and MT at an absolute workload of 126 pace per minute both with and without the addition of hand/ankle weights, it was found that both METS and Caloric expenditure were higher with weights than without, but the two pieces of equipment did not differ on these two variables (see Tables 2 and 4). Thus, the first hypothesis, that the MT would have a higher metabolic expenditure at an absolute workload, was incorrect. As seen in Table 6, the average heart rate was higher with than without weights, showing a higher intensity was attained with the addition of the weights. On the other hand, the heart rate did not differ between the two pieces of equipment, showing that 126 pace per minute was a similar intensity on both the TM and MT. The finding that additional weight increases metabolic expenditure coincides with studies that showed increased energy cost, with the use of weights at the same movement speed (126 pace per minute) (Bastein, Willems, Schepens, Heglunch, 2005; Epstein et al., 1988; Graves et al., 1988; Keren et al., 1981; Putthoff et al., 2006; Smith et al., 1995). The selected intensity of 126 pace per minute was based on the step frequency of an aerobic session on the MT of a beginners' level video provided by Airobix Inc.

Metabolic Cost at the Relative Workload

When testing the difference between the TM and MT at a relative workload of 65-85% HRR both with and without the addition of hand/ankle weights, it was found that both METS and Caloric expenditure were higher on the TM than the MT, but the addition of hand/ankle weights did not affect the result (see Tables 3 and 5). Thus, the second hypothesis, that the MT would have a higher metabolic expenditure at a relative workload, was also incorrect. As seen in Table 7, the average heart rate was higher on the TM as compared to the MT, showing that a higher intensity was attained on the TM. This was true even though the goal was to attain similar heart rates. In fact, subjects never reached the target heart rate on the MT. As seen in Table 1, the average goal for heart rate was between 147 and 176 bpm, but the subjects only reached an average of 137 bpm on the MT, compared to 146 bpm on the TM (see Table 7).

The researcher noted that it was difficult for participants to obtain and then maintain the target heart rate on the MT. A possible explanation is that on the TM it is possible for subjects to use the console to increase the speed (intensity), which in turn would help to increase heart rate. On the MT, however, the movement is dependent on the subject's self-generated movement speed, which may not allow an easy method to increase the intensity of the exercise. For example, the average pace per minute needed to obtain the target heart rate was 159 pace per minute on the TM (155 pace per minute with weights and 163 pace per minute without) versus 188 pace per minute on the MT (182 pace per minute with weights and 192 pace per minute without). Heart rate also did not show any differences when comparing exercise performed with weights and without (see Table 7). This may be due to the low amount of load added by the weights (3.6 kg). In contrast, Graves et al., (1988) and Smith et al., (1995) found that to cause any increase in metabolic cost of TM walking, or on a MT at a pace of 120 pace per minute, the minimum effective additional weight was approximately 1.36 kg.

Contact Forces

It was hypothesized that the MT would produce lower contact forces than the TM. In contrast to the initial hypothesis, the MT showed higher contact forces than TM regardless of the addition of hand/ankle weights. This observation was largely attributed to the surface types. The accommodating surface of the MT seemed more likely to reduce impact forces. However, Kerdok et al. (2002) and Mercer & Vance, 2002 found that the differences in surfaces leading to increased contact forces, and thus the impact on joints are not true. The reason appears to be that subjects tend to make internal anatomical adjustments to meet the demands of the surfaces and maintain the mechanical efficiency (Nigg, 2001).

The differences in the pattern of movement between the two pieces of equipment may be one possible reason for the lower contact forces on the TM. The contact forces are distributed in a forward - backward direction, and in the vertical direction on the TM. In contrast, on the MT, the contact forces are primarily in the vertical direction (S. Bullard, personal communication, January 22, 2007). Also, it was thought that jogging on the MT would occur with a higher center of gravity, which could possibly lead to higher contact forces. Keller et al. (1996) showed that jogging at a slower speed with a higher center of gravity, results in greater impact forces. In the same study the author suggested that higher contact forces might be reduced with a lower, more stable or fixed center of gravity while running at a slow or a fast speed such as on a TM. While no biomechanical data was recorded to support this explanation in the present study, the Keller et al. data is consistent with the present study.

It was also hypothesized that for each piece of equipment, the addition of hand/ankle weights would increase the contact force. This was also not found to be true, as the main effect for weight was found not to be significant (see Table 8). This indicates that the amount of weight (3.6 kg) used in the present study was not enough to increase contact force. This may be useful information for those that would like to utilize a low load without the risk of joint injury, although more research is needed on the relationship of contact force and injury rates of various activities, including exercise on the MT.

The F-Scan system yielded unexpected and inconsistent contact force data. The portable contact force measurement system, used in this study, had not been previously used to collect ground reaction forces on a MT or on a TM. A study on F-Scan in-shoe measurements by Woodburn and Helliwell (1996), detailed some of the weaknesses of the system. However, the author of the current study found the system stable during pilot data collection but regrettably found inconsistent data in the more extensive data collection. The system was most compatible with the requirements of the study to collect and measure contact forces for movement on a MT and a TM. The possibilities of lack of repeatability and reliability should be a caveat for future studies attempting to collect data with this equipment.

Conclusions

The MT may be affordable and convenient for exercising at home, and at an absolute load (set pace), the MT has a comparable metabolic expenditure to the TM. However, it may be easier to reach higher exercise intensity on the TM as opposed to the MT. Therefore, when jogging or walking on a MT, one may not reach the desired intensity level for improving fitness, as seen by the difficulty in reaching a target heart rate on the MT in the current study.

The use of additional weights may help burn more calories on the MT, and may help raise exercise intensity at an absolute workload, but this is true for the TM as well. An individual may also experience additional contact forces on the MT, and although this is not likely to cause injury (Dixon et al., 2000; Dura et al., 1999; Feehery, 1986; Ferris et al., 1998; Kerdok et al., 2002; Mercer & Vance, 2002; Nigg, 2001; Nyska et al., 1997; Tillman et al., 2002), it should be taken into consideration.

Future Recommendations

The use of a more proficient and reliable system for data collection of contact forces is recommended. Similar studies can be attempted with different age groups including children. MT use may help avoid childhood obesity. Generally jumping and bouncing on MT is viewed as a ‘fun’ activity. It may motivate kids to adopt exercise and associate ‘fun’ with MT exercises. However, injuries related to MT in that age group have been reported (Shields, Fernandez, & Smith, 2005). A definite protocol on the MT for achieving cardio-respiratory benefits and for weight loss programs for obese individuals can also be developed.

REFERENCES

Armstrong, L., Balady, G. J., Berry, M .J., Davis, S. E., Davy, B. M., Davy, K. P., et al., (2006). *American College of Sports Medicine's Guidelines to Exercise Testing and Prescription*, 7th edition, Lippincott Williams & Wilkins, Philadelphia, PA.

Bastein, G. J., Willems, P. A., Schepens, B, & Heglunch, N. C. (2005). Effect of load and speed on the energetic cost of human walking. *European Journal of Applied Physiology*, *94*, 76-83.

Bhattacharya, E. P., McCutcheon E. S., & Greenleaf, J. E. (1980). Body acceleration distribution and O2 uptake in humans during running and jumping. *Journal of Applied Physiology*, *49*(5), 881-884.

Blair, S. N., & Brodney, S. (1999). Effects of physical inactivity and obesity on morbidity and mortality: Current evidence and research issues. *Medicine and Science in Sports and Exercise*, *31*(Special Section), 646-62.

Blair, S. N., Cheng, Y., & Holder, J. S. (2001). Is physical activity or fitness more important in defining health benefits? *Medicine and Science in Sports and Exercise*, *33*(6) (Supplementary), 379-99.

Blair S. N., Kohl H. W., Paffenbarger, R. S. Jr., Clark D. G., Cooper K. H., & Gibbons, L. W. (1989). Physical fitness and all-cause mortality. A prospective study of healthy men and women. *The Journal of the American Medical Association*, *262*, 2395-401.

Blair S. N., Kohl H. W. III, Barlow C. E., Paffenbarger, R. S. Jr., Gibbons, L. W., & Macera C. A. (1995). Changes in physical fitness and all-cause mortality. A prospective study of health and unhealthy men. *The Journal of the American Medical Association*, *273*, 1093-8.

Bunc, V., & Dlouha, R. (1997). Energy cost of treadmill walking. *Journal of Sports Medicine and Physical Fitness*, *37*, 103-109.

Clement, D. B., Taunton, J. E. (1981). A guide to the prevention of running injuries. *Australian Family Physician*, *10*, 156-164.

Department of Health and Human Services (1991). *Healthy people 2000 national health promotion and disease prevention objectives: Full report, with commentary.* DHHS publication, no. (PHS) 91-50212. Washington, D.C.: Public Health Service

Dirkx, J. H. (Ed.) (2001). Stedman's concise medical dictionary for the health professionals illustrated (4th ed.) Philadelphia, PA: Lippincott Williams and Wilkins.

Dixon S. J., Collop A. C.; & Batt M. E. (2000). Surface effects on ground reaction forces and lower extremity kinematics in running. *Medicine and Science in Sports and Exercise*, *32*(11) 1919-26.

Dunn A. L., Marcus B. H, Kampert J. B., Garcia M. E., Kohl H. W. 3rd, & Blair S. N. (1999). Comparison of lifestyle and structured interventions to increase physical activity and cardiorespiratory fitness: A randomized trial. *The Journal of the American Medical Association*, *281*(4), 327-34.

Dura, J. V., Hoyos, J. V., Lozano, L., & Martinez A. (1999). The effect of shock absorbing sports surfaces in jumping. *Sports Engineering*, *2*, 103-108.

Epstein Y., Rosenblum J., Burstein R. & Sawka M. N. (1988). External load can alter the energy cost of prolonged exercise. *European Journal of Applied Physiology*, *57*(2), 243-247.

Feehery, R. V. Jr. (1986). The biomechanics of running on different surfaces. *Clinics in Podiatric Medicine and Surgery*, *3*(4), 649-659.

Ferris, D. P., Louie M., & Farley C. T. (1998). Running in the real world: Adjusting leg stiffness for different surfaces. *The Royal Society*, *265*, 989-994.

Gerberich, S. G., Leon, A. S., McNally C., Serfass R., & Edin, J. B. (1990). Analysis of the acute physiologic effects of minitrampoline rebounding exercise. *Journal of Cardiopulmonary Rehabilitation*, *10*, 395-400.

Graves, J. E., Martin A. D., Miltenberger L. A., & Pollock M. L. (1988). Physiological responses to walking with hand weights, wrist weights, and ankle weights. *Medicine and Science in Sports and Exercise*, *20*(3), 265-271.

Katch V. L., Villanacci, J. F., & Sady, S. P. (1981). Energy- cost of rebound running. *Research Quarterly for Exercise and Sport*, *52*(2), 269-272.

Keller, T. S., Weisberger, A. M., Ray, J. L., Hasan S. S., Shiavi, R. G., & Spengler, D. M. (1996). Relationship between vertical ground reaction force and speed during walking, slow jogging, and running. *Clinical Biomechanics*, *11*(5), 253-259.

Kerdok, A. E., Biewerner, A. A., McMahon, T. A., Weyand, P. G., & Herr, H. M. (2002). Energetics and mechanics of human running on surfaces of different stiffnesses. *Journal of Applied Physiology*, *92*, 469-478.

Keren, G., Epstein Y., Magazanik A., & Sohar, E. (1981). The energy cost of walking and running with and without a backpack load. *European Journal of Applied Physiology and Occupation Physiology*, *46*(3), 317-324.

McKenzie D. C., Clement D. B., & Taunton J. E., (1985). Running shoes, orthotics and injuries, *Sports Medicine*, *2*(5), 334-47.

Mercer, J. A., Vance, J. (2002). Spring-boots can reduce impact in runners. *Biomechanics*. Retrieved on September 30 2005, from http://www.biomech.com/db_area/archives/2002/0205.footwear.bio.shtml .

Moyna, N. M., Robertson, R. J., Meckes, C. L., Peoples, J. A., Millich, N. B., & Thompson, P. D. (2001). Intermodal comparison of energy expenditure at exercise intensities corresponding to the perceptual preference range. *Medicine and Science in Sports and Exercise*, *33*(8), 1404-1410.

Nigg, B. M. (2001). The role of impact forces and foot pronation: A new paradigm. *Clinical Journal of Sports Medicine*, *11*, 2-9.

Nyska, M., Linge, K., McCabe, C., Klenerman, L. (1997). The adaptation of the foot to heavy loads: Plantar pressures study. *Clinical Biomechanics*, *12*(3), pp S8.

Peterson, M. J., Palmer, D. R., & Laubach, L. L. (2004). Comparison of caloric expenditure in intermittent and continuous walking bouts. *Journal of Strength and Conditioning Research*, *18*(2), 373-376.

Putthoff, M. L., Darter, B. J., Nielsen, D. H., & Yack, J. H. (2006). The effect of weighted vest walking on metabolic responses and ground reaction forces. *Medicine and Science in Sports and Exercise*, *38*(4), 746-752.

Shields, B. J., Fernandez, S. A., & Smith, G. A. (2005). Comparison of minitrampoline and full-sized trampoline–related injuries in the United States, 1990 – 2002. *Pediatrics*, *116*, 96-103.

Smith, J. F., & Bishop, P. A. (1988). Rebounding exercise: Are the training effects sufficient for cardio-respiratory fitness? *Sports Medicine*, *5*, 6-10.

Smith, J. F., Bishop, P. A., Ellis, L., Conerly, M., & Mansfield, E. R. (1995). Exercise intensity increased by addition of hand-held weights to rebounding exercise. *Journal of Cardiopulmonary Rehabilitation*, *15*, 34-38.

The American Heritage Dictionary of the English Language, 4th Edition. Retrieved November 2, 2006, from Dictionary.com website: http://dictionary.reference.com/browse/Metabolism.

Tillman M. D., Fiolkowski P., Bauer J. A. & Reisinger K. D. (2002). In shoe plantar measurements during running on different surfaces: Changes and temporal and kinematic parameters. *Sports Engineering*, *5*, 121-28.

Warburton, D. E. R, Nicol C. W., Bredin, S. S. D. (2006a). Health benefits of physical activity: The evidence, *Canadian Medical Association Journal*, *174*(6), 801-09.

Warburton, D. E. R, Nicol C. W., & Bredin, S. S. D. (2006b). Prescribing exercise as preventive therapy, *Canadian Medical Association Journal*, *174*(7), 961-74.

Woodburn J., & Helliwell, P. S. (1996). Observations on the F-Scan in-shoe pressure measuring system, *Clinical Biomechanics*, *11*(5), 301-304.

APPENDIX A: IRB Approval Notice

OHIO UNIVERSITY

Office of the Vice President for Research

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Office of Research Compliance
[illegible]
[illegible]
www.ohiou.edu/research

The following research study has been approved by the Institutional Review Board at Ohio University for the period listed below. This review was conducted through an expedited review procedure as defined in the federal regulations as Category(ies):

4

Project Title: A Comparative Study between Rebounding Exercise and Walking for Metabolic Costs and Impact of Contact Forces on Joints in a Population between the Ages of 18 and 30 Years

Researcher(s):
Palak Shah
Roger Gilders
Susan Bullard
Michael Kushnick

Faculty Advisor (if applicable):

Department: Sport and Recreation Science

Rebecca G. Cale

Rebecca G. Cale, Assoc. Director
Research Compliance
Institutional Review Board

10/25/05
Approval Date

10/24/06
Expiration Date

This approval is valid until expiration date listed above. If you wish to continue beyond expiration date, you must submit a periodic review application and obtain approval prior to continuation.

Adverse events must be reported to the IRB promptly, within 5 working days of the occurrence.

The approval remains in effect provided the study is conducted exactly as described in your application for review. Any additions or modifications to the project must be approved by the IRB (as an amendment) prior to implementation.

APPENDIX B: Ohio University Consent Form

Title of Research

A Comparative Study of Treadmill Walking/ Jogging and Mini-trampoline Jogging for Metabolic Cost and Contact Forces.

Principal Investigator: Palak Shah

Co-Investigator: Dr. Rana, Dr. Bullard, Dr. Gilders, Dr. Kushnick

Department: School of Recreation and Sport Sciences, Ohio University, Athens, Ohio 45701

Federal and university regulations require signed consent for participation in research involving human subjects. After reading the statements below, please indicate your consent by signing this form.

Explanation of Study

Purpose of the Research

The aim of this study is to determine if are any differences in the two modalities with metabolic costs and contact force impact with and without external loads, and if there is any benefit to the use of mini-trampoline, to that of the treadmill, at the same comparable intensity (at a set heart rate range) and also metronome set pace.

Data Collection for Metabolic Expenditure

Procedures to be Followed

This is a non-invasive comparative study between different exercise modalities for caloric expenditure and impact of movement and load on the joints. The subjects will be tested at two different sessions. There will be an orientation session for the participants. We will be comparing a treadmill versus a mini-trampoline both with and without weights.

Weights include two pound hand and ankle weights each. One session will involve keeping the heart rate at a set range and comparing the 4 trials, and the other session will involve keeping the pace constant and comparing the 4 trials.

Orientation Day

Session 1:

At a set heart rate range, Trials are in a random order.

Trial 1: treadmill without weights each for 10 minutes

Rest 8 min,

Check weight, if loss of more then 1/10 of a kilogram, provide 100 ml of bottled drinking water.

Trial 2: mini-trampoline without weights each for 10 minutes

Rest 8 min

Check weight, if loss of more then 1/10 of a kilogram, provide 100 ml of bottled drinking water

Trial 3: treadmill with weights each for 10 minutes

Rest 8 min

Check weight, if loss of more then 1/10 of a kilogram, provide 100 ml of bottled drinking water

Trial 4: mini-trampoline with weights each for 10 minutes

Check weight, if loss of more then 1/10 of a kilogram, provide 100 ml of bottled drinking water

Session 2:

At a set tempo/pace. Trials are in a random order.

Trial 1: treadmill without weights each for 10 minutes

Rest 8 min

Check weight, if loss of more then 1/10 of a kilogram, provide 100 ml of bottled drinking water

Trial 2: mini-trampoline without weights each for 10 minutes

Rest 8 min

Check weight, if loss of more then 1/10 of a kilogram, provide 100 ml of bottled drinking water

Trial 3: treadmill with weights each for 10 minutes

Rest 8 min

Check weight, if loss of more then 1/10 of a kilogram, provide 100 ml of bottled drinking water

Trial 4: mini-trampoline with weights each for 10 minutes

Check weight, if loss of more then 1/10 of a kilogram, provide 100 ml of bottled drinking water

After the sessions are complete the collected data will be analyzed.

Duration of Subject's Participation:

A total of 75 minutes approximately (Preparation and set up time: 15 minutes) for metabolic expenditure data collection

A total of 20 minutes approximately (Preparation and set up time: 15 minutes) for contact force data collection.

Data Collection for Contact forces

Session: At a set tempo/pace. Trials are in a random order.

Trial 1: Mini-trampoline without weights at 126 pace per minute for 8 seconds

Rest: 1 minute

Trial 2: Mini-trampoline with weights at 126 pace per minute for 8 seconds

Rest: 1 minute

Trial 3: Treadmill without weights at 126 pace per minute for 8 seconds

Rest: 1 minute

Trial 4: Treadmill with weights at 126 pace per minute for 8 seconds.

Identification of Specific Procedures those are Experimental

Risks and Discomfort

Risks include no more than what it is for a regular exercise session. This includes increase in heart rates, blood pressure, sweating, dizziness, muscle soreness, and mild fatigue. The investigators are trained in CPR, AED and First Aid. Heart rate range will be pre-determined for the set intensity and pace, which is within a safe limit, for all the subjects. Rest between each trial and a cool down after all the trials, will be conducted to reduce the effects of fatigue and muscle soreness.

Benefits

Participant population is targeted to be from a college. Subjects will be learning few important aspects of exercise, working at an appropriate level, exercise techniques, and importance of posture and its role in force impact on joints with differing modalities.

Subjects will receive a report of the calories expended on each of the 4 trials, and the explanation of the interpretation of their results. Also, individual reports of force contact on each trial between their feet and the surface, of the two modalities, shall be explained after interpretation, and be informed of the differences if any.

Benefits to the Society

Our society should be better informed about the different exercise modes available for gaining health benefits. If we find that the mini-trampoline offers equivalent or better caloric expenditure with less impact on the foot, it will allow us to inform the general population about the benefits of this mode of exercise. Mini-trampolines are not currently a very popular mode of exercise, although could be a cost-effective alternative to treadmills, since treadmills cost upwards of $1000, which is much more than a mini-trampoline.

Alternative Treatments (if applicable)

N/A

Confidentiality and Records

Records, raw data and personal information will not be shared or disclosed to third party, other than the team of investigators and those involved in the project, as a part of the research team, for any purposes of research, to third party. Confidentiality of the subjects will be respected and all subjects will be treated with equality. The records will be under secured supervision, for a period of five years, and shall be eliminated, once the data has been analyzed, verified and determined.

Compensation

No compensation or incentive is being provided to the participants. The participants may ask for description of their personal data and results, and what is applicable to them, as participants, and value of their contribution and benefits to the society, by their participation.

Contact Information

If you have any questions regarding this study, please contact:

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If you have any questions regarding your rights as a research participant, please contact Jo Ellen Sherow, Director of Research Compliance, Ohio University, (740)593-0664.

I certify that I have read and understand this consent form and agree to participate as a subject in the research described. I agree that known risks to me have been explained to my satisfaction and I understand that no compensation is available from Ohio University and its employees for any injury resulting from my participation in this research. I certify that I am 18 years of age or older. My participation in this research is given voluntarily. I understand that I may discontinue participation at any time without penalty or loss of any benefits to which I may otherwise be entitled. I certify that I have been given a copy of this consent form to take with me.

Signature Date

Printed Name

APPENDIX C: Pre-exercise Testing Health Status Questionnaire

Ohio University

Exercise Physiology Laboratory

CODE:_______________________________ Date________________

Home Address____

Work Phone__________________ Home Phone________________

Person to contact in case of emergency_____________________________________

Emergency contact phone________________________

Personal Physician______________________________

Sex: M F Age_____yrs Height_____ft____in Weight_____lbs

Does the above weight indicate: a gain___ a loss___ no change___ in the past year?

If there is a change, how many pounds? ________________lbs

Do you consume alcohol regular basis?_____________________

Have you in the past, or do you currently use drugs?_______________________

A. Joint-Muscle Status (Check areas where you previously or currently have had related injuries)

This study involves walking and jogging at a pace similar to walking, with or without weights. Please check the area(s) of joints and muscle(s) where you have had any previous or currently have any injury (-ies) that might limit your activity.

Joint Areas	Muscle areas
( ) Shoulders	( ) Shoulders
( ) Elbows	( ) Arms
( ) Wrists	( ) Chest
( ) Upper Spine and Neck	( ) Upper Back and Neck
( ) Lower Spine	( ) Abdominal Regions
( ) Hips	( ) Lower Back
( ) Knees	( ) Buttocks
( ) Ankles	( ) Thighs
( ) Feet	( ) Lower Leg
( ) Other______________	( ) Feet
( ) Other_______________	

B. Health Status (Check if you previously had or currently have any of the following conditions)

( ) High Blood Pressure	( ) Acute Infection
( ) Heart Disease or Dysfunction	
( ) Peripheral Circulatory Disorder	( ) Anemia
( ) Lung Disease or Dysfunction	( ) Hernias
( ) Arthritis or Gout	( ) Thyroid Dysfunction
( ) Edema	( ) Pancreas Dysfunction
( ) Epilepsy	( ) Liver Dysfunction

(   ) Multiple Sclerosis   (   ) Kidney Dysfunction

(   ) High Blood Cholesterol or Triglyceride levels

(__) Diabetes or Blood Sugar Level Problems

(   ) Others that you feel we should know about:_________________________________

(   ) Allergic Reactions to Medication or Any Other substances; please describe below:

____

C. Physical Examination History

Approximate date of your last physical examination_______________________________

Physical problems noted at that time____

Has a physician ever made any recommendations relative to limiting your level of physical exertion? ____________YES   _____________NO

If YES, what limitations were recommended?

____

D. Current Medication Usage (List the drug name and condition being managed)

MEDICATION	CONDITION
___________________________	___________________________
___________________________	___________________________
___________________________	___________________________

E. Physical Perceptions (Indicate any unusual sensations or perceptions. (Check if you have recently experienced any of the following during or soon after physical activity (PA); or during sedentary periods (SED))

PA	SED		PA	SED	
( )	( )	Chest Pain	( )	( )	Nausea
( )	( )	Heart Palpitations	( )	( )	Light Headedness
( )	( )	Unusually Rapid Breathing	( )	( )	Loss of Balance
( )	( )	Overheating	( )	( )	Loss of Coordination
( )	( )	Muscle Cramping	( )	( )	Extreme Weakness
( )	( )	Muscle Pain	( )	( )	Numbness
( )	( )	Joint Pain	( )	( )	Mental Confusion
( )	( )	Other____________________			

F. Family History (Check if any of your blood relatives: parents, brother(s), sister(s), aunt(s), uncle(s), and grandparents, have or had any of the following)

( ) Heart Disease

( ) Heart Attacks or Strokes (prior to age 50)

( ) Elevated Blood Cholesterol or Triglyceride Level

( ) High Blood Pressure

( ) Diabetes

( ) Muscular Dystrophy

( ) Sudden Death (other than accidental)

G. Current Habits (Check any of the following if they are characteristic of your current habits)

( ) Frequently participates in a fitness class, or uses aerobic training equipment

( ) Frequently goes for long walks

( ) Frequently rides a bicycle

( ) Frequently jogs/runs for exercise

( ) Regularly participates in a weight training program

( ) Engage in a sports program more than once a week. If so, what does that program consist of?____

APPENDIX D: Karvonen's Method for Calculation of Target Heart Rate Range with % Heart Rate Reserve

HR Reserve Method (Karvonen)

(Armstrong et al., 2006)

The Heart rate reserve (HRR) is a method in which resting heart rate (HRrest) is subtracted from the maximal heart rate (HRmax) to obtain HRR. (Armstrong et al., 2006)

Target Heart rate range = ([HRmax – Hrrest] * percent intensity) + HRrest

The HRmax was an estimate using the formula of (220-age) for each subject. The inherent error is carried over in the antecedent calculation formula for Target Heart Rate range for % Heart rate Reserve. (Armstrong et al., 2006). Usually an error of approximately 11 beats per minute can be accounted with the age based prediction of the HRmax.

The percent intensity for both TM and MT was set to be between 65% - 85%.

65% - 85% of the HRR is equal to about 65% to 85% of VO2max for most fit individuals, but is more closely related to the %VO2R across the entire range of fitness levels. This latter fact is important when prescribing exercise to lower fit individuals (Armstrong et al., 2006).