UNIVERSITY OF WISCONSIN-LA CROSSE

Graduate Studies

PLANTAR FORCES DURING LOWER EXTREMITY EXERCISE ON THE FREEBOUNDER™ IN COMPARISON TO A TREADMILL AND A MINI-TRAMPOLINE

A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Clinical Exercise Physiology

Megan M. Thiel

College of Science and Health
Clinical Exercise Physiology

December, 2018

PLANTAR FORCES DURING LOWER EXTREMITY EXERCISE ON THE FREEBOUNDER™ IN COMPARISON TO A TREADMILL AND A MINI-TRAMPOLINE

By Megan M. Thiel

We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree of Master of Science in Clinical Exercise Physiology

The candidate has completed the oral defense of the thesis.

John Porcari, Ph.D. Thesis Committee Chairperson	4/6/18 Date
Naghmeh Gheidi, Ph.D. Thesis Committee Member	4.6.18 Date
Susan Bramwell, M.S. Thesis Committee Member	4.6.18 Date

Thesis accepted

Meredith Thomsen, Ph.D. Graduate Studies Director	5-7-18 Date

ABSTRACT

Thiel, M.M. Plantar forces during lower extremity exercise on the Freebounder™ in comparison to a treadmill and a mini-trampoline. MS in Clinical Exercise Physiology, December 2018, 49pp. (J. Porcari)

The purpose of this study was to examine ground reaction force and loading rate while exercising on the Freebounder™. Nine male (age 21.7 ± 2.74 years) and nine female (age 21.2 ± 1.58 years) subjects performed a 1-minute exercise bout which included walking on a treadmill, running on a treadmill, double-leg bouncing on a mini-trampoline, and double-leg bouncing on a Freebounder™. Data were recorded using in shoe sensors during the last 10 seconds of each trial with the five most representative strides being analyzed. It was found that ground reaction force and loading rate on the Freebounder™ were significantly lower than the other three conditions. It was concluded that the Freebounder™ is a low-impact exercise alternative compared to traditional modes of exercise.

ACKNOWLEDGEMENTS

I wish to extend my deepest appreciation to my family for their unwavering support and guidance throughout all my years of schooling and continuing to believe in my abilities. I would like to thank all of the participants in my study for their time and cooperation, without you, I would not have had the opportunity to complete my thesis. In addition, I would like to thank my thesis committee for helping throughout this process. The knowledge base you have all instilled in me as I took on a task I had not done before was greatly appreciated. And lastly, to my fellow classmates, I wish to thank you all for a great year of knowledge and friendship.

TABLE OF CONTENTS

LIST OF FIGURES

FIGURE PAGE

LIST OF APPENDICES

APPENDICES PAGE

INTRODUCTION

When choosing a weight bearing activity to incorporate into an exercise regimen, impact forces may dictate which exercise, piece of machine, or surface an individual chooses. Impact forces can range from body weight up to 12 times body weight, depending on the exercise (Hreljac, 2004). Modes of exercise that generate low impact forces may be useful for individuals looking to avoid jarring movements or athletes who are looking to rehabilitate an injury. Additionally, loading rate (i.e., the rate at which those impact forces are transmitted to the body) represents a strong predictor of injury risk (Davis, Bowser, & Mullineaux, 2015).

Rebounding has been of interest as an exercise modality since its emergence as a training tool for elite athletes in the 1970s (Esposito & Esposito, 2009). Trampoline exercise has also been used as a rehabilitation device. Improvements in mobility and activities of daily living were found in stroke patients who trained on mini-trampolines compared to patients who participated in similar exercises on level ground (Miklitsch, Krewer, Freivogel, & Steube, 2016). Exercises included the patients lifting their heels and walking in place while on the mini-trampolines.

Rebounders are considered low-impact because they are a compliant surface. Rebounders absorb and decrease the amount of impact endured by the joints, particularly in the lower extremities (McGlone, Kravitz, & Janot, 2002). Plyometric exercises, such as depth jumps and counter movement jumps occurring on a mini-trampoline, or rebounder, and the ground were studied by Crowther, Spinks, Leicht, and Spinks (2007).

They found the compliant surface resulted in a reduction in impact forces during jump training.

Several studies have investigated the cardiovascular response to exercising on mini-trampolines. A study conducted by NASA in the 1970s concluded that aerobic training on a trampoline was as effective at improving VO_2max as running (Bhattacharya, McCutcheon, Shvartz, & Greenleaf, 1978). It was also determined that heart rate and VO_2 showed similar linear relationships while running on a treadmill and jumping on a mini-trampoline. Burandt, Porcari, Cress, Doberstein, & Foster (2016) found that mini-trampolines offered sufficient intensity to improve cardiorespiratory fitness. The study also found that exercise on a mini-trampoline burned the same number of calories as running 6 miles per hour on flat ground (Burandt et al., 2016).

The Freebounder™ Fitness and Rehab Machine, invented by John Louis (Northfield, IL), came on the market in February of 2017. It consists of a spring loaded platform attached to a metal frame and has rebounding characteristics similar to those of mini-trampolines. The Freebounder™ is marketed as low-impact because it purportedly reduces the impact forces put on the body during an aerobic workout.

Although, numerous studies have investigated the cardiovascular response to rebounder exercise, there is very little data on the forces acting on the lower extremities during this type of exercise. The purpose of this study was to determine the impact forces put on individuals when exercising on the Freebounder™ and compare those to impact forces when walking and running on a treadmill and double-leg bouncing on a mini-trampoline.

METHODS

Subjects

Eighteen apparently healthy male and female volunteers between 19-28 years old were recruited from the University of Wisconsin – La Crosse. All subjects completed a PAR-Q to screen for known cardiovascular and orthopedic contraindications to exercise. Eligible subjects provided written informed consent prior to participating in the study. The study was approved by the University of Wisconsin – La Crosse Institutional Review Board for the Protection of Human Subjects.

Procedures

Subject's height and weight were measured and dominant foot was determined prior to the start of the study. Dominant foot was determined by asking subjects with which foot they would kick a soccer ball. Subjects then completed 4 conditions; walking on a treadmill, running on a treadmill, double-leg bouncing on a mini-trampoline, and double-leg bouncing on a Freebounder™. Each condition was 1-minute in duration and the order of conditions was randomized. For the treadmill test, subjects completed one session of walking and one session of running on a motorized treadmill. Walking was conducted at 3 miles per hour, while running was at 6 miles per hour. The pace remained constant throughout both walking and running sessions and treadmill incline was set at 0% for both trials.

For the mini-trampoline test, subjects were shown the double-leg bounce on the mini-trampoline and then were allowed to practice until they felt comfortable. The pace was set at 80 beats per minute. Once subjects were deemed proficient on the mini-trampoline, they were tested. On the Freebounder™, the spring tension of the Freebounder™ was adjusted based upon body weight, where each spring added equals approximately 7.5 pounds of resistance. Subjects were shown the double-leg bounce exercise, known as active recovery, and subjects were allowed to practice until they felt comfortable on the machine. Once subjects became proficient, the measurement session began. The pace was set at 60 beats per minute.

For all testing, plantar forces were collected using Loadsol® in shoe sensors (Novel Electronics, Inc, St. Paul, MN) within the subjects' dominant shoe. Data was recorded during the last 10 seconds of each trial, with the 5 most representative strides being analyzed for vertical ground reaction force (GRF) and loading rate (LR). All sessions took place in the Human Performance Laboratory (HPL) on the UW – La Crosse campus.

Figure 1 depicts a GRF graph with a heel-strike pattern for subject 12. The impact peak, also referred to as the passive peak in some literature, is the initial force at heel contact. The slope of the line from ground to impact peak is used to calculate LR. The steeper the line, the higher the loading rate, and the quicker the force is applied to the exerciser. This is in comparison to a less steep slope, where it takes longer for the force to be applied to the exerciser. The active peak is the function of the force applied by the foot and supported by body weight during mid-stance.

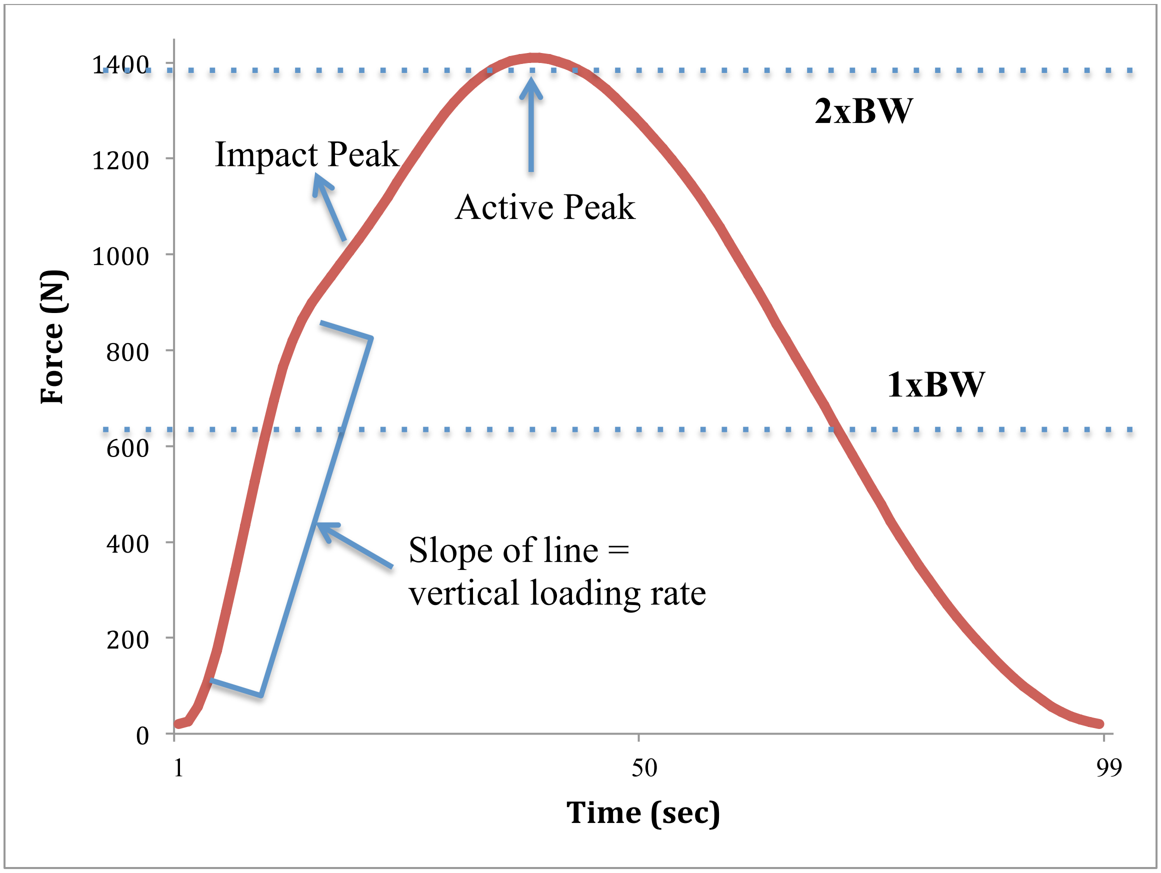

Figure 1. Running GRF for subject 12.

STATISTICAL ANALYSIS

Standard descriptive statistics were used to summarize the data. Ground reaction force and LR were compared between the four conditions using one-way ANOVA with repeated measures. When there was a significant F-ratio, pairwise comparisons were made using Tukey's post-hoc tests. Alpha was set at .05 to achieve statistical significance. Data were analyzed using SPSS version 25.0

RESULTS

The descriptive characteristics of the subjects who participated in the study are presented in Table 1. The age range of subjects was 19-28 years.

Table 1. Descriptive characteristics of subjects (N=18).

	Men (n=9)	Females (n=9)
Age (years)	21.7 ± 2.74	21.2 ± 1.58
Height (cm)	180.1 ± 6.25	171.9 ± 5.39
Weight (kg)	86.1 ± 21.15	69.3 ± 11.34

Values represent mean ± standard deviation.

The responses to the Freebounder™ Fitness and Rehab Machine are presented in Table 2. It was found that GRF and LR were significantly lower for the Freebounder™ compared to walking, jumping on a mini-trampoline, and running.

Table 2. Vertical ground reaction force (GRF) and loading rate (LR) during the four different exercise conditions.

	GRF (Newtons)	LR (Newtons/sec)
Freebounder	564 ± 126.2	518 ± 260.2
Walking	918 ± 232.5*	5315 ± 1094.1*
Mini-trampoline	1415 ± 353.2*	7454 ± 1898.1*
Running	1668 ± 395.4*	14555 ± 3895.7*

Values represent mean ± standard deviation.
*Significantly different than the Freebounder™ ($p<.05$).

The comparison of GRF, relative to body weight, during the four conditions is displayed in Figure 2. The comparison of LR, relative to body weight per second, during the four conditions is displayed in Figure 3.

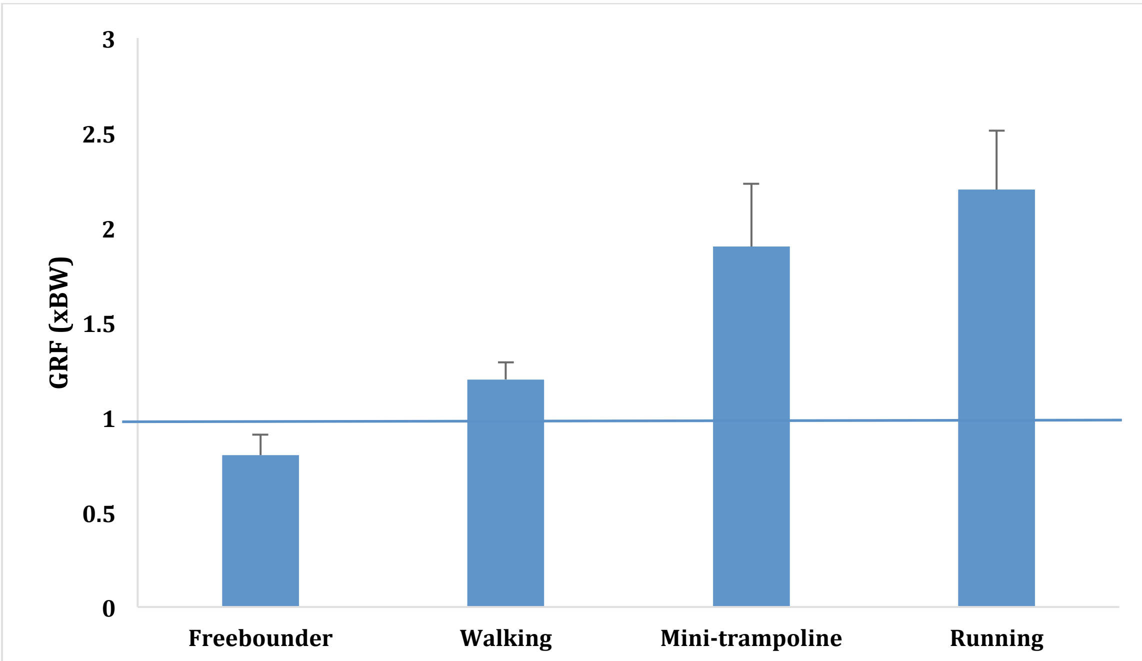

Figure 2. Mean GRF during the four conditions relative to body weight.

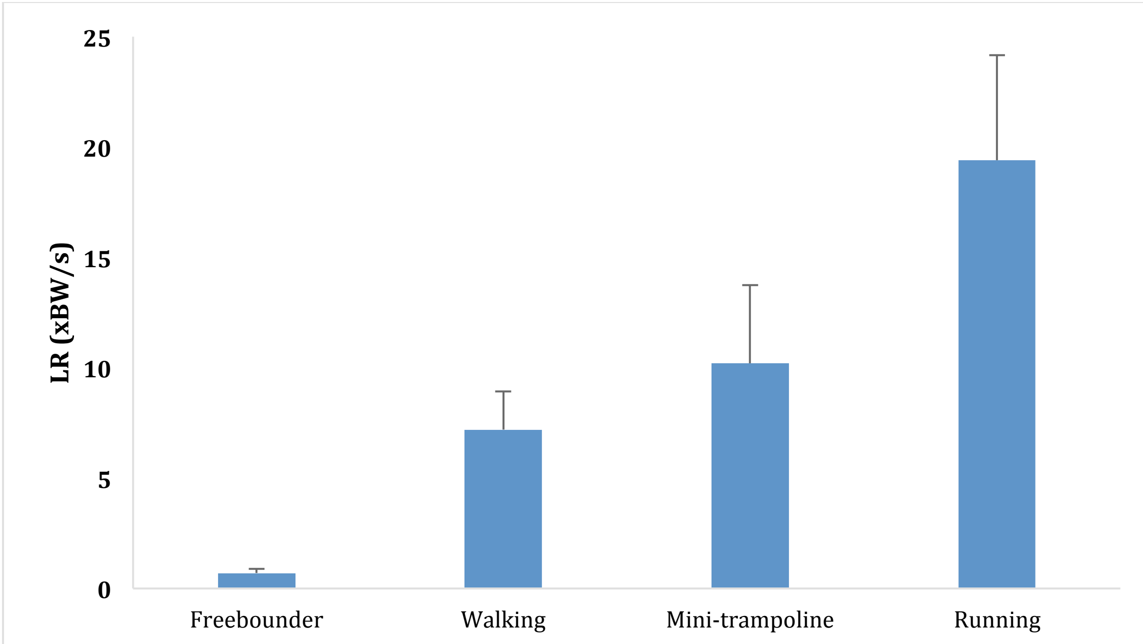

Figure 3. Mean LR during the four conditions relative to body weight per second.

DISCUSSION

The purpose of this study was to examine plantar force in the lower extremities associated with exercising on the Freebounder™ Fitness and Rehab Machine in comparison to walking and running on a treadmill and bouncing on a mini-trampoline. The current study found that subjects had lower GRF when exercising on the Freebounder™ compared to all other conditions. The GRF (Newtons) on the Freebounder were 63% lower than walking, 151% lower than bouncing on a mini-trampoline, and 196% lower than running, respectively. Relative to body weight, the GRF when exercising on the Freebounder™ was .75 times body weight; walking was 1.2 times body weight, bouncing on the mini-trampoline was 1.9 times body weight, and running was 2.2 times body weight.

The results of this study are consistent with findings of Porcari and Foster (2000) who found that running on a treadmill generated GRF approximately 2.5 times body weight. In that study, the GRF for using an elliptical was approximately equal in magnitude to the subject's own body weight. Burnfield, Jorde, Augustin, Augustin, and Bashford (2007) compared the plantar pressures when exercising on five different cardiovascular machines. Comparable to Porcari and Foster (2000), they found the elliptical to have lower pressures than those found in running. The results of the abovementioned studies are similar to what was found with the Freebounder™.

Lower impact forces are considered beneficial, since high GRF can result in a higher risk of injury, especially in runners (Lopes, Hespanhol, Yeung, & Costa, 2012).

Hrelaj (2004) concluded that runners who acquire training habits that reduce impact forces and minimize the effect forces have on the body could be at a lower risk for developing injuries. The spring-loaded platform of the Freebounder™ can be beneficial in minimizing injury or for rehabilitation since the platform acts as a compliant surface where the platform absorbs some of the force applied to it and therefore is not applying as much force back to the user.

Similar to GRF, LR was lower on the Freebounder™ compared to all of the other conditions. The LR (Newtons/second) on the Freebounder™ was 926% lower than walking, 1,339% lower than bouncing on the mini-trampoline, and 2,709% lower than running on the treadmill, respectively. In terms of body weight, the LR of the Freebounder™ was .65 body weight per second (BW/s); walking was 7.2 BW/s, bouncing on the mini-trampoline was 10.2 BW/s, and running was 19.4 BW/s. Dixon, Collop, and Batt (2000) found that there was a lower LR in runners who ran on a rubber-modified surface compared to conventional asphalt. As part of their testing, the researchers dropped a weighted sphere onto the surfaces and found that the rubber-modified surface had greater impact absorption than the asphalt surface. Again, this impact absorption mirrors the spring-loaded platform of the Freebounder™, which acts as a compliant surface and slows down the forces that are applied to the exerciser.

A lower LR when exercising is also considered beneficial because it signifies a reduced speed at which forces impact the body. Davis et al. (2015) examined runners who had a history of injury and those who had not sought medical treatment for injury. It was found that vertical average LR was lower in the runners who had never been injured compared with those who had and sought medical treatment. Thus, decreasing LR should help minimize tissue stress to the user. Since the Freebounder™ is not applying forces to the body as quickly compared to running, walking, or bouncing on a mini-trampoline, the injury potential should be reduced compared to those modalities.

A possible limitation in the current study was that the active recovery exercise that was used during testing was not easy for all subjects to learn because it was not a common motion that most individuals use when exercising on traditional cardiovascular equipment. Even though subjects were required to practice on each modality before they were tested, with more practice it is possible subjects would feel more relaxed with performance of the active recovery exercise. Whether this would have affected the force data is unknown.

To our knowledge, this is the first research project to be conducted relative to the impact forces when exercising on the Freebounder™. Future research may want to evaluate potential improvements in balance and coordination associated with exercising on the Freebounder™. Additionally, the enjoyment of exercising on the Freebounder™ should be compared to other cardiovascular equipment, as exercise enjoyment is a strong factor in exercise adherence.

In summary, it was found that the GRF and LR of the Freebounder™ Fitness and Rehab Machine were lower when compared to walking and running on a treadmill and double-leg bouncing on a mini-trampoline. These findings suggest that the Freebounder™ is an excellent low-impact option for individuals looking for an alternative compared to traditional modes of exercise.

REFERENCES

Bhattacharya, A., McCutcheon, E.P., Shvartz, E., Greenleaf, J.E. (1980). Body acceleration distribution and O_2 uptake in humans during running and jumping. *Journal of Applied Physiology, 49*(5), 881-887.

Burandt, P., Porcari, J.P., Cress, M.L., Dobestein, S., & Foster, C. (2016). Putting mini-trampolines to the test. *ACE Prosource™, October,* 1-3.

Burnfield, J.M., Jorde, A.G., Augustin, T.R., Augustin, T.A., & Bashford, G.R. (2007). Variations in plantar pressure variables across five cardiovascular exercises. *Medicine & Science in Sports & Exercise, 39*(11), 2012-2020.

Crowther, R.G., Spinks, W.L., Leicht, A.S., & Spinks, C.D. (2007). Kinematic responses to plyometric exercises conducted on compliant and noncompliant surfaces. *Journal of Strength and Conditioning Research, 21*(2), 460-465.

Davis, I. S., Bowser, B. J., & Mullineaux, D. R. (2015). Greater vertical impact loading in female runners with medically diagnosed injuries: a prospective investigation. *British Journal of Sports Medicine*, *50,* 887-892.

Dixon, S.J., Collop, A.C., & Batt, M.E. (2000). Surface effects on ground reaction forces and lower extremity kinematics in running. *Medicine & Science in Sports & Exercise, 32*(11), 1919-1926.

Esposito, P.W., & Esposito, L.M. (2009). The reemergence of the trampoline as a recreational activity and competitive sport. *Current Sports Medicine Reports, 8*(5), 273-277.

Hreljac, A. (2004). Impact and overuse injuries in runners. *Medicine & Science in Sports & Exercise, 36*(5), 845-849.

Lopes, A. D., Hespanhol, L. C., Yeung, S. S., & Costa, L. O. P. (2012). What are the main running-related musculoskeletal injuries?. *Sports Medicine*, *42*(10), 891-905.

McGlone, C., Kravitz, L., & Janot, J.M. (2002). Rebounding: A low-impact exercise alternative. *ACSM's Health & Fitness Journal, 6*(2), 11-15.

Miklitsch, C., Krewer, C., Freibogel, S., & Steube, D. (2013). Effects of predefined minitrampoline training programme on balance, mobility and activites of daily living after stroke: A randomized controlled pilot study. *Clinical Rehabilitation, 27*(10), 939-947.

Porcari, J., & Foster, C. (2000). Exercise response to elliptical trainers. *Fitness Management*, 1, 1-3.

APPENDIX A

INFORMED CONSENT FORM

INFORMED CONSENT

PLANTAR FORCES DURING LOWER EXTREMITY EXERCISE ON THE FREEBOUNDER™ IN COMPARISON TO A TREADMILL AND A MINI-TRAMPOLINE

I, ______________________, volunteer to participate in a research study being conducted by the University of Wisconsin – La Crosse.

Purpose and Procedures

- The purpose of this study is to examine impact forces in the feet associated with exercising on the Freebounder™ Fitness and Rehab Machine in comparison to walking and running on a treadmill and using a mini-trampoline.

My participation will involve:

- A total of approximately 1 hour in the Human Performance Laboratory in Mitchell Hall.
- During this session, I will:
    - Walk on a level treadmill for 1 minute.
    - Run on a level treadmill for 1 minute.
    - Jump on a mini-trampoline for 1 minute.
    - Bounce on the Freebounder™ for 1 minute.
- I will be given a familiarization period on the Freebounder™ and the mini-trampoline prior to testing.
- During all tests, I will wear Loadsol® in-shoe sensors, which are inserts placed in each shoe, to measure impact forces.

Potential Risks

- There are no foreseeable risks associated with this study other than fatigue and muscle soreness.
- The risk of serious complications is very low in a regularly exercising, apparently-healthy population. If an emergency should occur, individuals trained in CPR and Advanced Cardiac Life Support (ACLS) will conducting the testing. The laboratory has a standard emergency plan and an Automated External Defibrillator (AED) is available in the laboratory where testing will take place.

Rights and Confidentiality

- My participation in this study is entirely voluntary and I can withdraw from the study at any time, for any reason, without penalty.
- In the event that the results of this study are published in the scientific literature, my name and personal information will not be identified.

- My results will remain confidential. Only the investigator and appropriate laboratory personnel will have access to my individual data.

Possible Benefits

- There are no primary benefits to myself other than knowledge about my impact forces when performing different exercises on various exercise machines.

Questions

- I have read the information provided on this consent form. I have been informed of the purpose of this study, the procedures, and expectations of myself and the testers, and of the potential risks and benefits that may be associated with volunteering for this study. I have asked any and all questions that concerned me and received clear answers so as to fully understand all aspects of this study.

- Any questions concerning this study may be directed to the primary investigator Megan Thiel (920-740-7754) or her supervisor Dr. John Porcari (608-785-8684). Questions regarding the protection of human subjects may be addressed to the UWL Institutional Review Board for the Protection of Human Subjects (608-785-8124).

______________________	______________________	__________
Subject Name (please print)	Signature	Date
______________________	______________________	__________
Witness Name (please print)	Signature	Date

APPENDIX B

PAR-Q FORM

2017 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	**YES**	**NO**
1) Has your doctor ever said that you have a heart condition ☐ OR high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** ______	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** ______	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it ***does not limit your current ability*** to be physically active. **PLEASE LIST CONDITION(S) HERE:** ______	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Go to Page 4 to sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow International Physical Activity Guidelines for your age (www.who.int/dietphysicalactivity/en/).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at **www.eparmedx.com** before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

OSHF

2017 PAR-Q+

FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1. Do you have Arthritis, Osteoporosis, or Back Problems?

If the above condition(s) is/are present, answer questions 1a-1c — If **NO** ☐ go to question 2

1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	YES ☐ NO ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	YES ☐ NO ☐

2. Do you currently have Cancer of any kind?

If the above condition(s) is/are present, answer questions 2a-2b — If **NO** ☐ go to question 3

2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck?	YES ☐ NO ☐
2b.	Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)?	YES ☐ NO ☐

3. Do you have a Heart or Cardiovascular Condition? *This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm*

If the above condition(s) is/are present, answer questions 3a-3d — If **NO** ☐ go to question 4

3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)	YES ☐ NO ☐
3c.	Do you have chronic heart failure?	YES ☐ NO ☐
3d.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	YES ☐ NO ☐

4. Do you have High Blood Pressure?

If the above condition(s) is/are present, answer questions 4a-4b — If **NO** ☐ go to question 5

4a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
4b.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	YES ☐ NO ☐

5. Do you have any Metabolic Conditions? *This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes*

If the above condition(s) is/are present, answer questions 5a-5e — If **NO** ☐ go to question 6

5a.	Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?	YES ☐ NO ☐
5b.	Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.	YES ☐ NO ☐
5c.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet?	YES ☐ NO ☐
5d.	Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?	YES ☐ NO ☐
5e.	Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?	YES ☐ NO ☐

2017 PAR-Q+

6. **Do you have any Mental Health Problems or Learning Difficulties?** *This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome*

If the above condition(s) is/are present, answer questions 6a-6b — If **NO** ☐ go to question 7

6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
6b.	Do you have Down Syndrome **AND** back problems affecting nerves or muscles?	YES ☐ NO ☐

7. **Do you have a Respiratory Disease?** *This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure*

If the above condition(s) is/are present, answer questions 7a-7d — If **NO** ☐ go to question 8

7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	YES ☐ NO ☐
7c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	YES ☐ NO ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	YES ☐ NO ☐

8. **Do you have a Spinal Cord Injury?** *This includes Tetraplegia and Paraplegia*

If the above condition(s) is/are present, answer questions 8a-8c — If **NO** ☐ go to question 9

8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	YES ☐ NO ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	YES ☐ NO ☐

9. **Have you had a Stroke?** *This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event*

If the above condition(s) is/are present, answer questions 9a-9c — If **NO** ☐ go to question 10

9a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
9b.	Do you have any impairment in walking or mobility?	YES ☐ NO ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	YES ☐ NO ☐

10. **Do you have any other medical condition not listed above or do you have two or more medical conditions?**

If you have other medical conditions, answer questions 10a-10c — If **NO** ☐ read the Page 4 recommendations

10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	YES ☐ NO ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	YES ☐ NO ☐
10c.	Do you currently live with two or more medical conditions?	YES ☐ NO ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE:

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

OSHF

01-01-2017

2017 PAR-Q+

If you answered NO to all of the follow-up questions about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that a Trustee (such as my employer, community/fitness centre, health care provider, or other designate) may retain a copy of this form for their records. In these instances, the Trustee will be required to adhere to local, national, and international guidelines regarding the storage of personal health information ensuring that the Trustee maintains the privacy of the information and does not misuse or wrongfully disclose such information.

NAME ______________________________ DATE ______________________________

SIGNATURE ______________________________ WITNESS ______________________________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________________

For more information, please contact
www.eparmedx.com
Email: eparmedx@gmail.com

Citation for PAR-Q+
Warburton DER, Jamnik VK, Bredin SSD, and Gledhill N on behalf of the PAR-Q+ Collaboration. The Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) and Electronic Physical Activity Readiness Medical Examination (ePARmed-X+). Health & Fitness Journal of Canada 4(2):3-23, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the BC Ministry of Health Services.

Key References
1. Jamnik VK, Warburton DER, Makarski J, McKenzie DC, Shephard RJ, Stone J, and Gledhill N. Enhancing the effectiveness of clearance for physical activity participation; background and overall process. APNM 36(S1):S3-S13, 2011.
2. Warburton DER, Gledhill N, Jamnik VK, Bredin SSD, McKenzie DC, Stone J, Charlesworth S, and Shephard RJ. Evidence-based risk assessment and recommendations for physical activity clearance; Consensus Document. APNM 36(S1):S266-s298, 2011.
3. Chisholm DM, Collis ML, Kulak LL, Davenport W, and Gruber N. Physical activity readiness. British Columbia Medical Journal. 1975;17:375-378.
4. Thomas S, Reading J, and Shephard RJ. Revision of the Physical Activity Readiness Questionnaire (PAR-Q). Canadian Journal of Sport Science 1992;17:4 338-345.

OSHF

01-01-2017

APPENDIX C

DATA COLLECTION FORM

Plantar Forces in Lower Extremities: Freebounder™, Treadmill, Mini-trampoline

Name: ___________________ ID:______________________

Date:____________________ Age:_____________________

Weight (kg):______________ Wt. Range (+/- 5%):________

Height:____________ Dominant Leg:____________

Shoe Size: _______________ Sensor #:_________________

Test: 60 seconds Record for last 10 seconds	Completed
Freebounder Tempo: 60 bpm	
Mini-trampoline Tempo: 80 bpm	
Walking Pace: 3 mph	
Running Pace: 6 mph	

APPENDIX D

PICTURE OF FREEBOUNDER™ MACHINE

APPENDIX E

REVIEW OF THE LITERATURE

Review of Literature

The purpose of this literature review is to discuss several topics relating to the Freebounder™, a full-body exercise machine, and the effects it has on impact forces put on the body, particularly in the lower extremities.

Outcomes of Rebound Training

The Freebounder™ Fitness and Rehab Machine, invented by John Louis, debuted in February 2017 at the American Physical Therapy Association Combined Sections Meeting. The Freebounder™ is marketed as a full-body exercise machine that can improve cardiovascular fitness as well as reduce impact forces put on the body during an aerobic workout. While the Freebounder™ lacks research around its capabilities due to the new nature of the machine, it has similar characteristics to the rebounding capabilities of a mini-trampoline.

Training in Athletes

The mini-trampoline emerged in the 1970s and is widely used in gyms as a training device when working with elite athletes (Esposito & Esposito, 2009). Benefits such as improving the height of vertical jumps in elite college basketball players have been associated with mini-trampoline training programs (Ross & Hudson, 1997). In addition to the prevalence of mini-trampoline training within the elite athlete population, mini-trampolines have also become popular in recreational and home use and have been suggested as a way to improve balance and coordination.

Physiological Responses to Rebound Training

A study conducted by NASA in 1978 was the first study on cardiovascular responses to rebound training. The goal of the study was to determine the best way for astronauts to avoid deconditioning while they were in space (Bhattacharya, McCutcheon, Shvartz, & Greenleaf, 1978). The study consisted of eight males completing walking and running at four different speeds on a treadmill as well as jumping on a trampoline at four different heights. Measurements of acceleration, heart rate, and VO_2 were taken on both modalities. The researchers concluded that training on a trampoline was as effective at improving VO_2max as running. It was also determined that heart rate and VO_2 showed similar linear relationships while running on a treadmill and jumping on a mini-trampoline. The researchers also found that the trampoline resulted in lower impact on the lower body.

Burandt, Porcari, Cress, Doberstein, and Foster (2016) also examined the physiological responses to trampoline training. Their study consisted of male and female subjects completing a 19-minute exercise routine on a mini-trampoline while measurements were taken for heart rate and VO_2. They found that mini-trampolines offered sufficient intensity to improve cardiorespiratory fitness. The study also found that exercise on a mini-trampoline burned the same number of calories as running 6 miles per hour on flat ground.

Rehabilitation Training

Improvements in balance and coordination have recently been studied in a clinical setting. In a pilot study, Miklitsch, Krewer, Freivogel, and Steube (2016) found that stroke patients could benefit from mini-trampoline training regimens when compared to group balance programs. The patients in the study demonstrated improvements in mobility and activities of daily living after preforming exercises such as shifting weight while standing, lifting heels, walking in place, jumping in place, and jogging in place. The training period within in this study included 10 sessions over 3 weeks for 30 minutes a session.

Impact Forces on the Body During Rebounding

Another reason that users seek out mini-trampoline exercises is because they offer a low-impact option over other exercise modalities. Mini-trampolines do not put as much stress the musculoskeletal system or joints, which can make the exercise activity less jarring, even though muscles are working hard (Burandt et al., 2016). Rebounders, or mini-trampolines, absorb and decreases the amount of impact endured by the joints, particularly in the lower extremities (McGlone, Kravitz, & Janot, 2002). This decrease in the amount of impact on the joints can especially be observed compared to high-impact activities such as jogging or basketball. This low-impact mode of exercise can be extremely beneficial for recreational users or athletes who are looking to prevent overuse injuries.

Palak Shah, a graduate student at Ohio University, studied contact forces when exercising on a mini-trampoline compared to a treadmill under two conditions; with and without hand and ankle weights (3.6 kg). His study included 7 men and 5 women who were healthy and between the ages of 18 and 30 years old. Subjects completed 4 randomized trials of 8 seconds at 126 pace per minute on each piece of equipment with and without weights (Shah, 2007). Contact forces were collected through the use of insole sensors for the whole foot area. Shah hypothesized that contact forces would be lower on the mini-trampoline; however, he found that, at a pace of 126, contact forces were actually higher on the mini-trampoline than the treadmill at the same pace, regardless of using weights.

Effect of Surface and Shoe Stiffness on Runners

Surface Stiffness

Dixon, Collop, and Batt (2000) examined surface stiffness and ground reaction forces in runners. Two surfaces were bituminous, which can be considered a flexible pavement that can bend and compress as a load is applied to it as well as bounce back. The first bituminous surface was a conventional asphalt and the second was a rubber-modified bituminous material, with the third surface being a synthetic sports surface consisting of an acrylic carpet on a thin shock pad. The three different surfaces were assessed using a standard impact test, to determine their mechanical impact absorbing features. At the conclusion of the impact test, which consisted of dropping a 6.8 kg sphere onto each of the three test surfaces, it was found that the rubber-modified asphalt surface and the synthetic sports surface provided greater impact absorption than the conventional asphalt surface. However, the synthetic sports surface, which included the shock pad, provided less absorption properties than the rubber-modified material.

To determine how runners respond to the three surfaces of different stiffness that were tested through the mechanical impact test, Dixon et al. (2000) recruited six female, well-trained, middle distance runners. Each subject completed 10 different randomized trials on each surface at a speed of 3.3 $m \cdot s^{-1}$. Each trial consisted of making left foot contact with a force plate, 15 meters down a runway of each surface, without altering running style to ensure force plate contact. Differences between the surfaces were not disclosed to subjects throughout the testing period. It was found that there was no significant difference in peak impact force among the surfaces. There was, however, a significant difference in reducing the loading rate of peak impact force. The rubber-modified surface showed a reduction compared to conventional asphalt. It was also observed that surface manipulation occurs in runners, meaning runners can individually adapt to the various surfaces to maintain the biomechanical requirements of the movement (Dixon et al., 2000).

In a similar study, Tillman, Fiolkowski, Bauer, and Reisinger (2002) observed reaction forces, ground contact times, and impulses in runners across four different surfaces with the use of in-shoe sensors. The researchers recruited 11 males (19-26 years old) who completed randomized trials on asphalt, concrete, grass, and a rubber running track. Each subject completed three running trials across a 20-meter runway of each surface. Subjects were instructed to complete each trial at their normal training pace so they could consistently reproduce individual running speed performance across each surface and trial. It was found that there was no significant difference in force, contact time with the surface, or impulse among the four different surfaces. Since different surfaces do not affect the force acting at the shoe foot interface while running, the authors concluded that runners are not subjecting themselves to greater injury risk when running on surfaces that vary in stiffness.

Kerdok, Bierman, McMahon, Wyand, and Herr (2002) also examined how runners respond to different surface stiffness. Eight males participated in the study, which consisted of running 5 minutes at 3.7 m/s on a level treadmill that was built to allow for the ability to adjust the platform to five different stiffness settings. Each subject completed 2 trials on each of the 5 surfaces the treadmill allows. Force plates were mounted in the treadmill to collect ground reaction forces of the runners during the fourth and fifth minutes of each trial to allow subjects to reach a steady state before collecting data. Because the running platforms on the treadmill are compliant, as it could return energy back to the subject, Kerdok et al. calculated the energy return of the treadmill platform. It was reported that runner's support mechanics remained unchanged across the four stiffest surfaces, with a small difference in the lowest stiffness surface. It was further concluded that runners compensate to the surface by altering leg spring stiffness to the surface so they do not modify their biomechanics.

Shoe Stiffness

Similar to the studies conducted on surfaces of varying stiffness, Aguinaldo and Mahar (2003) compared different types of cushioning shoes. Two of the shoes consisted of cushioning column systems, with the third being a top model running shoe. Within their study, subjects, eight male and two female, ran across a 12-meter runway at a self-selected stride making contact with a force plate. Three trials were collected for each of the three shoe types that were tested. The researchers found that the loading rates of the running trials for both column systems were lower than found in other shoes. The researchers further went on to conclude that the loading rate pattern may be a better indicator of cushioning abilities because of the speed at which shock is transmitted to the lower extremities.

Comparing Overground and Treadmill Running

In a slightly different direction, Riley et al. (2008), compared treadmill running with overground running kinematics and kinetics. Twenty men and women (ages 20-29) who ran or jogged at least 15 miles each week were recruited from the local population. Subjects ran at a self-selected 10 kilometer race pace for 15 meters on an overground runway to capture 3 strides of each leg. The treadmill test consisted of subjects running at their average speed, calculated from the overground trials, to capture 15 consecutive gait cycles. Overground ground reaction force measurements were collected using in-ground force plates while treadmill measurements were collected via an instrumented treadmill. When examining the ground reaction force data, the study found reductions in peak propulsive anterior and peak medial ground reaction forces when running on the instrumented treadmill compared to the overground trials. However, there were no significant differences in vertical ground reaction force for either the overground or treadmill trials, most likely because energy was transferred to the runner from the treadmill. While on the treadmill, average vertical ground reaction force was 99.5% of subject body weight.

Hong, Wang, Li, and Zhou (2012) conducted a similar study examining plantar load measurements during treadmill and two overground running surfaces. Sixteen right leg dominant, male, amateur runners (21-24 years old) participated in the study. Five trials were completed by each participant for each surface: treadmill, concrete, and grass, with right foot phase from heel-strike to toe-off measurements collected via in-shoe sensors. Treadmill measurements were obtained during the last minute of a 2-minute run at 3.8 m/s while concrete and grass measurements were taken during a 5 meter measurement zone on a 15 meter runway, at the same velocity as the treadmill. While contact times did not differ amongst the 3 surfaces, total foot maximum plantar pressure did differ. The two overground surfaces did not differ in maximum plantar pressure of the total foot, but the treadmill did demonstrate lower forces when compared to both overground surfaces. Due to the lower plantar pressure in treadmill running, it was suggested that treadmill running may be a useful rehabilitation application compared to overground running.

Outcomes of Cardiovascular Equipment

Plantar pressures were also examined across five cardiovascular exercises conducted on different equipment to determine variations in impact forces (Burnfield, Jorde, Augustin, Augustin, & Bashford, 2007). Twenty subjects were divided into two equal groups: young (19-35 years old) and middle-aged (45-60 years old) and instructed to complete 4 trials, lasting 5 minutes each at a self-selected speed on various pieces of equipment. Equipment included a treadmill (measuring while both walking and running), an elliptical trainer, a stair climber, and a recumbent bicycle. Pressure measurements of the subjects were taken by in-shoe sensors of the dominant foot during the final minute of each trial. Plantar pressures were evaluated in three areas of the foot, including forefoot, arch, and heel. There were variations in plantar pressure amongst the exercises and it was concluded the primary cause was the change in maximum force of the reference limb when preforming the exercise tasks. For example, periods of single limb support, such as running, differed when compared to the elliptical, which had double limb support, or the recumbent bicycle that allows buttock support of the subject. The variations found in the study included, peak plantar pressure in the forefoot being higher in walking, running, and the elliptical versus stair climber or recumbent bicycle. For the arch, pressures were higher in running compared to all other exercises and the heel showed higher peak pressure during walking and running compared to the three other exercises. The findings in this study can have a relationship to injury rehabilitation or avoidance in a clinical setting.

Porcari and Foster (2000) also examined vertical ground reaction forces put on the feet while exercising on various cardiovascular machines. The researchers were particularly interested in the elliptical, due to the new nature of the machines at the time of the study. Sixteen subjects (27-54 years old) were recruited to participate in the study that included the use of an elliptical trainer, running or walking on a treadmill, a step machine, and a cycle ergometer. Subjects were instructed to complete 5 minutes on each machine, at a self-selected speed, while insole sensors measured their vertical ground reaction forces. It was found that the vertical ground reaction forces during the elliptical were comparable to those found in walking, while running on the treadmill generated forces approximately 2.5 times subject body weight.

Results of Plyometric Exercises and Speed

Plyometric Exercises

Crowther, Spinks, Leicht, and Spinks (2007) studied the effects of plyometric exercises, depth jumps and counter movement jumps, conducted on a compliant surface, a mini-trampoline, and the ground. Twenty males (18-25 years old) recruited for the study performed 10 jumps on one surface and after 7 days, performed 10 jumps on the other surface. The surface jumps were completed in a random order and three of each jump were randomly selected from each individual for data analysis. The compliant surface resulted in a reduced crouch action in jumping, which allowed for greater maximum leg power and acts as a reduction property of impact forces during jump training.

Parkour Landing

To determine the effects of the relatively new Parkour discipline, Puddle and Maulder (2013) examined ground reaction forces and loading rates of Parkour landing when compared to traditional landing techniques. Their study consisted of 10 male subjects who completed three types of drop landings; Parkour precision landing, roll landing, and traditional landing (those typically seen in sports such as basketball) from a platform onto a force plate. Five trials were used from each type of landing. It was concluded that the Parkour precision landing and Parkour roll landings had lower maximal vertical forces and slower times to maximal vertical force. The lower loading rates of both Parkour landings indicate that they are safer for subjects than that of the traditional landing.

Speed

To observe the connection between speed and ground reaction forces, Keller et al. (1996) compared walking and slow jogging, between speeds of 1.5–3.0m•s^{-1} and running between 3.5–6.0 m•s^{-1} on a 12 meter running platform. Ground reaction forces were collected via a force plate. The highest impact forces were observed during slow jogging compared to slow walking or fast running. This high impact forces during slow jogging occur because the center of gravity is higher and less fixed.

Injuries Associated with Running and Jumping

Running

Hreljac (2004) examined overuse injuries, particularly in runners. There is no standard definition of overuse injuries, but common overuse injuries associated with running include, but are not limited to, stress fractures, plantar fasciitis, and Achilles tendinitis. Hreljac classified overuse factors into three overall categories: training, anatomical, and biomechanical. For example, training errors are specific to individuals, as one could react differently than another during identical training patterns. Training factors include going beyond one's limit of distance or intensity, which would not result in positive remodeling of body tissue. The researcher concluded that runners who acquire training habits that reduce impact forces and minimize the effect forces have on the body and therefore can be at a lower risk for developing injuries. This conclusion aligns with the findings of Lopes, Hespanhol, Yeung, and Costa (2012) who determined that the risk of injury is greater due to high impact forces, especially in runners.

Davis, Bowser, and Mullineaux (2015) concluded that loading rate, the speed at which forces are applied to the body, is also a strong predictor of injury risk in runners. To come to this conclusion, the researchers examined 249 female runners over a 2-year period and assigned them to either an injury group, for those who had a history of injury and sought medical treatment, and an uninjured group. It was found that vertical average loading rate was lower in the runners who had never been injured compared with those who had sought medical treatment.

Jump-Landing

Bell, Pennuto, and Trigsted (2016) examined jump-landing vertical ground reaction forces after exertion to understand how they could play a role in injury, particularly ACL injury, between sexes. Twenty males and 20 females (18-23 years old) who were recreationally active participated in the study. The study consisted of subjects preforming 5 drop landings from a 30 centimeter tall box that was half their height onto force plates and immediately jumping as high as possible, before and after a fatiguing protocol. The fatigue protocol consisted of subjects sprinting in between cone formations, preforming wall sits, 10 vertical jumps, and planks and the circuits were repeated until the subjects reported a rating of perceived exertion (RPE) of 17 (6-20 scale). Results of the study illustrate that men and women react to exertion differently with men landing with greater vertical ground reaction forces and loading rate compared to the females in the study. However, vertical ground reaction asymmetry was not influenced by sex or exertion, as previously related to ACL injuries.

Weight Bearing Activities Can Affect Bone Health

While it is difficult to outline a specific exercise program for peak bone mass in individuals of all ages, weight-bearing exercises, that are preformed safely, have beneficial effects on bone health (Kohrt, Bloomfield, Little, Nelson, & Yingling, 2004). Impact forces can range from 10-12 times body weight in jump landing, 1.5-5 time body weight in running, and slightly higher than body weight in walking (Hreljac, 2004). Korht et al. (2004) conclude that in children, bone mass is higher in those who participate in activities such as gymnastics due to high impact forces, than those who partake in low impact activities, such as walking. Walking, which does produce low impact forces, could however, result in bone fatigue (Boudenot, Achiou, & Portier, 2015). In adults, it can be inferred that moderate to high impact activities, such as stair climbing or volleyball, can help preserve bone health (Korht, et al., 2004).

Miller et al. (2006) studied bone health in 87 master athletes (65 years old and older) at the Summer Senior Olympics in Pittsburgh, Pennsylvania. They compared those athletes participating in high impact running, to those participating in swimming, a low impact activity. What they found was that master athletes in both impact categories, high and low, have higher bone mineral density, compared to individuals of the same age who do not participate in high or low impact activities.

Summary

Weight bearing exercises that are preformed safely are beneficial to bone health. Impact forces are an important factor when choosing an exercise regimen, modality or surface, especially if the goal is to avoid jarring movements or injury. The Freebounder™ is a new exercise machine that can give an individual a non-traditional rebounding workout. To our knowledge, the impact forces during Freebounder™ activity have not been researched. Evaluation of the impact on lower extremities while using the Freebounder™ will provide insight into the level of impact this new machine has on the lower body.

REFERENCES

Aguinaldo, A., & Mahar, A. (2003). Impact loading in running shoes with cushioning column systems. *Journal of applied biomechanics*, *19*(4), 353-360.

Bhattacharya, A., McCutcheon, E.P., Shvartz, E., Greenleaf, J.E. (1980). Body acceleration distribution and O_2 uptake in humans during running and jumping. *Journal of Applied Physiology, 49*(5), 881-887

Bell, D.R., Pennuto, A.P., & Trigsted, S.M. (2016). The effect of exertion and sex on vertical ground reaction force variables and landing mechanics. *The Journal of Strength and Conditioning Research, 30(*6), 1661-1669.

Boudenot, A., Achiou, Z., & Portier, H. (2015). Does running strengthen bone?. *Applied Physiology, Nutrition, and Metabolism*, *40*(12), 1309-1312.

Burandt, P., Porcari, J.P., Cress, M.L., Dobestein, S., Foster, C. (2016). ACE SPONSORED RESEARCH: Putting mini-trampolines to the test. *Sign, 8,* 825-3636

Burnfield, J.M., Jorde, A.G., Augustin, T.R., Augustin, T.A., & Bashford, G.R. (2007). Variations in plantar pressure variables across five cardiovascular exercises. *Medicine & Science in Sports & Exercise, 39*(11), 2012-2020.

Crowther, R.G., Spinks, W.L., Leicht, A.S., & Spinks, C.D. (2007). Kinematic responses to plyometric exercises conducted on compliant and noncompliant surfaces. *Journal of Strength and Conditioning Research, 21*(2), 460-465.

Davis, I. S., Bowser, B. J., & Mullineaux, D. R. (2015). Greater vertical impact loading in female runners with medically diagnosed injuries: a prospective investigation. *British Journal of Sports Medicine*, *50,* 887-892

Dixon, S.J., Collop, A.C., & Batt, M.E. (2000). Surface effects on ground reaction forces and lower extremity kinematics in running. *Medicine & Science in Sports & Exercise, 32*(11), 1919-1926.

Esposito, P.W. & Esposito, L.M. (2009). The reemergence of the trampoline as a recreational activity and competitive sport. *Current Sports Medicine Reports, 8*(5), 273-277.

Hreljac, A. (2004). Impact and overuse injuries in runners. *Medicine & Science in Sports & Exercise, 36*(5), 845-849.

Hong, Y., Wang, L., Li, J.X., & Zhou, J.H. (2012). Comparison of plantar loads during treadmill and overground running. *Journal of Science and Medicine in Sport, 15*, 554-560.

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., Biewener, 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.

Kohrt, W. M., Bloomfield, S. A., Little, K. D., Nelson, M. E., & Yingling, V. R. (2004). Physical activity and bone health. *Medicine & Science in Sports & Exercise*, *36*(11), 1985-1996.

Lopes, A. D., Hespanhol, L. C., Yeung, S. S., & Costa, L. O. P. (2012). What are the main running-related musculoskeletal injuries?. *Sports Medicine*, *42*(10), 891-905.

McGlone, C., Kravitz, L., & Janot, J.M. (2002). Rebounding: A low-impact exercise alternative. *ACSM's Health & Fitness Journal, 6*(2), 11-15.

Miklitsch, C., Krewer, C., Freibogel, S., & Steube, D. (2013). Effects of predefined minitrampoline training programme on balance, mobility and activites of daily living after stroke: A randomized controlled pilot study. *Clinical Rehabilitation, 27*(10), 939-947.

Miller, M.E., Wagner, J. M., Vujevich, K. T., Medich, D. L., Velez, N., Zhang, A., Perera, S., &Greenspan, S.L. (2006). The effect of high versus low impact exercise on skeletal integrity in master athletes. *Journal of Bone and Mineral Research, 21*, S376

Porcari, J., & Foster, C. (2000). Exercise response to elliptical trainers. *Fitness Management*, 1, 1-3.

Puddle, D. L., & Maulder, P. S. (2013). Ground reaction forces and loading rates associated with parkour and traditional drop landing techniques. *Journal of sports science & medicine*, *12*(1), 122.

Riley, P.O., Dicharry, J., Franz, J., Croce, U.D., Wilder, R.P., & Kerrigan, C.D. (2008). A kinematics and kinetic comparison of overground and treadmill running. *Medicine & Science in Sports & Exercise, 40*(6), 1093-1100.

Ross, A.L., & Hudson, J.L. (1997). Efficacy of a mini-trampoline program for improving the vertical jump. *Biomechanics in Sport XV*, 63-69.

Shah, P.V. (2007). A comparative study of treadmill walking/jogging and mini-trampoline jogging for metabolic cost and contact forces. (Masters Thesis). Retrieved from https://etd.ohiolink.edu/rws_etd/document/get/ohiou1195077861/inline

Tillman, M.D., Fiolkowski, P., Bauer, J.A., & Reisinger, K.D. (2002). In-shoe plantar measurements during running on different surfaces: Changes in temporal and kinetic parameters. *Sports Engineering, 5*, 121-128.