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Effect of Treadmill Exercise Durations on Balance Ability Measured by Sway Balance Application

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EFFECT OF TREADMILL EXERCISE DURATIONS ON BALANCE ABILITY MEASURED BY SWAY BALANCE APPLICATION

BY

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To the Dean of the School of Human Performance and Leisure Sciences:

I am submitting herewith a thesis written by Mohammad Zougar entitled "Effect of Treadmill Exercise Durations on Balance Ability Measured by Sway Balance Application". I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science with a major in Movement Science.

Dr. Claire Egret, Thesis Committee Chair

We, members of the thesis committee,
have examined this thesis
and recommend its acceptance:

Accepted:

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Table of Contents

LIST OF TABLES	**VI**
LIST OF FIGURES	**VII**
CHAPTER I	**VIII**
INTRODUCTION	**8**
BACKGROUND	**8**
PURPOSE OF THE STUDY	**11**
RESEARCH HYPOTHESIS	**13**
RATIONALE	**14**
SIGNIFICANCE OF THE STUDY	**16**
STATEMENT OF THE PROBLEM	**18**
RESEARCH OBJECTIVES	**18**
LIMITATIONS	**19**
DELIMITATIONS	**19**
ASSUMPTIONS	**20**
INDEPENDENT VARIABLES	**20**
DEPENDENT VARIABLES	**21**
OPERATIONAL DEFINITIONS	**21**
SUMMARY OF THE CHAPTER	**22**

LITERATURE REVIEW **24**

1..BALANCE CONTROL **24**

2. CONCEPTUAL MECHANISM OF BALANCE **26**

3. TYPES OF BALANCE **27**

4.CONCEPT OF TREADMILL EXERCISES ON BALANCE AND WARMING UP **28**

5.EFFECTS OF FATIGUE ON BALANCE CONTROL **29**

6.ANKLE MUSCULATURE FATIGUE **30**

7. THE IMPACT OF FATIGUE ON BALANCE **36**

8. DURATION AND RECOVERY FROM FATIGUE EFFECTS **36**

9. BALANCE ASSESSMENT METHODS **38**

10.VALIDATION OF ACCELEROMETERS IN BALANCE ASSESSMENT **40**

11. FALL AND INJURY RISKS DUE TO POOR BALANCING **42**

12. GAPS IN THE REVIEW OF LITERATURE **44**

CHAPTER III **47**

METHODS **47**

PARTICIPANTS **47**

INSTRUMENTATION **47**

PROCEDURES **51**

BALANCE PROTOCOL **51**

RUNNING PROTOCOL **53**

DATA ANALYSIS **56**

REFERENCES **57**

MANSCRUPIT ERROR! BOOKMARK NOT DEFINED.

APPENDIX **93**

APPENDIX A: RECRUITMENT FLYER **94**

APPENDIX B **95**

APPENDIX C **97**

List of Tables

Table 1: Anthropometric Measurements of the Subjects **Error! Bookmark not defined.**

Table 2:Target Heart Rate Calculation. 50

Table 3: Each Subject Have to follow This Instructional Steps 54

Table 4: Anthropometric Measurements of the Subjects **Error! Bookmark not defined.**

List of Figures

Figure 1: Balance Framework Hypothesis (Davidson, et al., 2009). 26

Figure 2: Rate of Perceived Exertion (RPE) scale used to indicate the level of fatigue. 49

Figure 3: Visual Analog Scale 50

Figure 4: Sway Balance Application Protocol. 52

Figure 5: The Foot Placements of the following Tests; Feet together, Semi-tandem, and Full Tandem or (Tandem) 52

Chapter I

Introduction

Background

It is noted that approximately 33% to 50% of a large portion of the population over the World experiences loss of balance after exercise (Whitney et al., 2011). The many-sided quality of control of balance results in a wide-range of balance issues that need orderly clinical evaluation for viable treatment. Much of the existing literature provides information based on effect of fatigue on balance for old individuals or for patients with different complications with the majority of the studies observed older adults or individuals with neurological or musculoskeletal deficits. However, there are few studies that studied the effect of exercising on balance for recreational population.

Loss of balance may lead to serious health challenges if it is not addressed on time. This prevents the accessibility of health services for intervening on poor coordination and loss of balance issues. The Sway Balance Application, which is based on accelerometric measurement of sway, offers an inexpensive and efficient alternative for quantifying posture control and provides excellent opportunities for on-line sway analyses (Boveet al., 2007). The method is reliable and can be used together with clinical balance and mobility tests in various circumstances, particularly in outcome and screening studies (Boveet al., 2007).

Balance is accomplished by incorporation and coordination of different body frameworks, including the vestibular, visual, auditory, and with the extensive contribution of visual spatial frameworks. Data from tactile frameworks is translated into the central nervous systems (CNS) in light of an inner body mapping. The relevant response is processed and communicated to the postural muscle to perform the head, eye, trunk, and appendage developments to look after stance. In order to maintain balance, it is required to accomplish the body center of mass (COM) with respect to the base of support (Boveet al., 2007).

In Biomechanics, the body balance is the capacity to keep up the line of gravity (vertical line from center of mass) of a body inside of the base of the support with negligible postural sway. Some of the activities considered as minor such as breathing, moving body weight from one foot to the next or from forefoot to rear foot or response to outside stimuli such as visual contortions and floor interpretations often necessitate a precise response. An increase in influence is mostly a marker of diminished sensorimotor control and less a measure of deviations (Paillard, 2012).

Alberts et al. (2013) noted that the Sway Balance is an FDA-cleared balance testing framework which utilizes the assembled part of a tri-pivotal accelerometers of a portable electronic gadget to trustily evaluate postural development. The framework was intended to give a method for quantitative balance evaluation in clinical and on-field situations. Human balance is a general term used to depict the coordination of complex tactile and biomechanical procedures with the end goal of keeping up one's center of mass (COM) on their base of support (BOS). The capacity to look after balance or postural dependability is a crucial segment that goes beyond facilitating an upward stance to allowing the performance of complex tasks. Balance enhancement has been indicated to help with recuperation from harm, damage aversion, and improved practical execution in both adults and elderly people. The capacity to rapidly and dependably survey balance for any populace, in any clinic, gym, or health setting is turning out to be progressively critical.

Hrysomallis (2011) explained that weakness modifies the power limit of muscles. There are complex and unpredictable neural components involved in this process. At the lower leg, it diminishes the feeling of position and the control of balance. For instance, previous researchers (Hrysomallis, 2011; Jorgensen, 2012) have inspected how plantar flexor and dorsiflexor exhaustion impelled through an isokinetic convention influenced the control of balance. Jorgensen (2012) and Hrysomallis (2011) noted that a significant increase in mediaolateral (M-L) body influence the extent of motions particularly during the exhausted state.

More worldwide fatigue methods where fatigue is affected by treadmill strolling or skiing, running or cycling likewise have been utilized. Conventions that utilize a vigorous training have reported increase in the center of pressure (CP) and middle recurrence of the CP speed. The last impact recommended by the authors is that exhaustion increases the body’s capacity to cope with the influence of motion (Hrysomallis, 2011).

Exhaustion after vigorous exercises is considered to influence the body balance in an individual. However, the level of stability after exercises depends on other factors, such as body weight, length of the exercises and type of activity engaged (Hrysomallis, 2011). It is important to have an inexpensive and easy to use measuring instrument that can take into account the relevant measurements that should be used in determining the effect that activities may lead to loss of balance.

Jorgensen (2012) reports a decrease in performance in a double task condition (diminished power generation and increased reaction time) contrasted with the single task. Jorgensen (2012) recommended that the double tasks condition forced a 100% workload on the subject's constrained attention requests. However, Jorgensen (2012) did not identify additional factors that can be associated with the expanded capacity to manage motion after exhaustion. Comparative intuitive procedures in the middle of insight and the balance control instruments have been proposed. For example, attentional requests are more prominent for unsteady than for stable balanced conditions.

Purpose of the study

Many studies that explored practices such as running and cycling (i.e., practices that extensively engage the entire body) discovered changes in balance control (Jorgensen, 2012). Research has additionally inspected the impacts of lower muscles fatigue (LMF). LMF refer to the fatigue of a particular muscle mass and it can be considered as the inability to keep up with energy demands. It can also be understood as the possibility of an activity to incite a decreased in the force yielded in that particular muscle group. The impacts of LMF on balance control have been investigated for a scope of particular muscle groups (i.e., lower leg musculature, hip musculature, lumbar extensors), exhaustion methods (i.e., isometric or isokinetic training), and balance assignments (i.e., single leg position, two-legged position and external balance recuperation) (Gutierrez et al., 2007). This research will investigate the effect of exercise duration that followed treadmill on the body balance by using Sway balance application.

Jorgensen (2012) added that there are various systems for evaluating balance that are both objective and subjective. Subjective evaluation techniques shift generally in testing philosophy. They incorporate an arrangement of testing and identify scoring strategies unique to the test identified. This approach has a tendency to be used in clinical settings. It's an executive test used in clinical learning to assess the patient. The advantages of these balance tests are that they are effortlessly regulated and demands practically zero hardware. On the other hand, while numerous have been accepted, they do not give quantifiable information and they depended on the ability and experience of the test clinician for scoring and interpretation.

Paillard (2012) found that target techniques for balance evaluation incorporate the utilization of power stages, exertion measures, and accelerometers. The advantages of these device are their capacity to create quantitative scores by which clinicians and analysts have the capacity to track changes over various tests. On the other hand, while these test systems have enhanced legitimacy and unwavering quality over subjective strategies, except for accelerometers, the hardware required is large and hard to transport. This makes equipment-based balance is hard to perform outside the clinic or a research facility environment. Accelerometers are little, lightweight, and ready to be connected to the subject. Furthermore, they have been demonstrated to be valuable for surveying balance among both static and dynamic activities. However, in spite of their favorable circumstances over other target measures, accelerometers are essentially utilized only as a part of research.

As innovation has propelled, there has been an increase in the predominance of purchaser devices, which join the utilization of numerous accelerometers. One such approach can be found in the iPod and iPhone created by Apple Inc. These frameworks join Micro Electro-Mechanical Systems (MEMS) Nano-accelerometers that measure the momentary quickening of an item, contrasted with gravity at any given time, in a free-fall reference outline. Estimations are experts utilizing a moveable bar suspended on micro-machined springs that evaluate speeding up by the bar's deviation as the gadget moves in reference to gravity. MEMS accelerometers ordinarily measure quickening autonomously and termed as tri-axial or tri-axis accelerometers (Gutierrez et al., 2007).

The idea of a remote accelerometer framework for evaluating the characteristics of walk and balance has been outlined through the G-link® Wireless Accelerometer Node and Apple iPod and iPhone. These devices have the ability to store information tests, which can be passed on remotely to a far area for post-processing. Studies have shown that the iPod and iPhone exhibit the ability to get precisely measured balance parameters with an adequate level of consistency (Paillard, 2012). However, advance studies are expected to keep on approving the exactness and unwavering quality of accelerometric cell phones.

Research Hypothesis

The present study assessed if the applicability of Sway Balance Mobile Application (Sway Medical) that was introduced to determine the effect of exercise durations on balance. Balance durations will have a significant effect on 30 minute group more than 20 minute group when they compared to the control group. The Sway Balance Mobile Application, introduced on the cell phone is produced from the tri-axial accelerometers to identify a balance (dependability) score. The results of the balance score refer to the quickening of avoidance within the accelerometers. The Sway test helped in the assessment of the effect of exercise duration that followed treadmill on the body balance by using Sway balance application. It presented a critical and easier modes of determining the influence that exercise has on an individual balance. The method is considered effective due to its applicability outside the laboratory and the easiness in transporting it from one region to another (Jorgensen, 2012).

Rationale

Bell et al. (2011) founded that the utilization of anaerobic exercises can impact balancing in an individual. Bell et al. (2011) added that there is proof to propose that the body balance tends to weaken after engaging in anaerobic exercises or in athletics. Along these lines, the same kind of guideline may help to minimize the negative impacts of exhaustion on balance control. The after-effects of this postulation are critical to help with creating particular instructional sets to enhance balance execution for those people who perform balance tasks under exhausting conditions (i.e. the worker in industry) or for those people who have balance issues and may impair the execution of exercises daily.

Rogers and Patterson (2012) concluded that balance tests can give incredible knowledge to paramedical services suppliers. From deciding potential fall hazards in seniors to distinguishing indications of loss of consciousness in competitors, testing balance assumes an imperative part in recognizing potential well-being dangers and additionally evaluating advancement. Rogers and Patterson (2012) also reported that the $60 billion sticker attached to our human services framework is distant from everyone else and worth investigating better devices and techniques for incorporating balance testing in any paramedical services supplier's tool kit. With such a large number of balance testing techniques, orthopedic damage results to observing reactions of solutions, to evaluating unconsciousness, the utilization of balance appraisal ought to be an easy decision.

The balance estimation has been ignored to some degree for the high cost of target balance testing (Rogers & Patterson, 2012). Conventional power stages are viewed as the best quality level in target balance testing and can cost upwards of $20,000 per machine. On the flip side of the range of these tests is organizational pencil and paper tests. The issue with these tests' results are subjective. As we make the movement towards results based-paramedical services, target devices will turn into an important piece of frequent practice. The test will be discovering the right devices that provide the most profit for the venture. Influence balance shows a novel open door for simple, convenient and Sway balance testing that gives social insurance suppliers a simple to utilize instrument to better track changes in balance (Rogers & Patterson, 2012).

Rogers and Patterson (2012) added that it is imperative to recall that in the place of balance control is needed to keep up postural steadiness as well as to guarantee safe versatility related exercises among daily life; for example, standing while performing manual tasks, ascending from a seat, strolling and turning. Disarranges of balance can be of the consequence of pathologies; for example, neurological sickness, tangible shortfalls or muscle shortcoming. Body balance is noted to be reduced when someone is engaged in vigorous activities such as athletics.

The current research does not expect to provide an extensive rundown of all accessible balance appraisal devices, but instead compresses the most ordinarily utilized ways to deal with survey balance, talk about the points of interest and impediments of each, and present new modernized devices to quantitatively assess the balance and the versatility execution in a clinical setting.

Significance of the Study

It is critical to understand the significance that balance has in the health of a person. From this research, it will be possible to relate the importance that understanding the significance of balance is crucial in the body. It is noted that anaerobic exercise influences the body balance to a large extent in the daily living of a person. As noted earlier, the other measuring tools that could be used to determine the effect of the exercise has on the balance are not easily applicable outside the laboratory due to the bulky nature of the equipment or due to difficulty of data collection and interpretation (Rogers & Patterson, 2012). However, with the integration of Sway balance application, it is found to be less expensive compared to other methods that could be used. In addition, it is important to note that the Sway balance application could be applied for self-assessment for patients with chronic illnesses.

By combining the treadmill knowledge and the exercise effect that has on the balance, it is important to identify an appropriate intervention for people like athletes or seniors. It is noted that understanding these effects will enhance the design and formulation of an effective intervention measurements for people who engage in vigorous activities. In addition, this research is critical in demonstrating the applicability of the Sway balance application in determining the influence of exercise on balance considering the application of a treadmill.

This research forms a valuable source of crucial information regarding effectiveness of Sway balance application that are inexpensive and easily applicable to people who engage in aerobic and anaerobic exercises. This information is crucial for health care professionals in designing appropriate measures for the balancing issues. Balance is considered critical in the performance of an individual in regard to healthy living. Most of the people over the world experience pressing balancing challenges that remain untreated due to the high cost associated with the measuring instruments used. By introducing the Sway balancing for measuring the impact that exercise has on balancing, it is a new measure that is cost-effective and efficient.

Whitney et al. (2011) added that developing knowledge-based application of the new technology will enhance the development of the society health concerns in respect to balance. Balance is a serious health concern that has received little attention due to high expenses in the purchasing of the equipment. Understanding the main goal of this research will help in designing an effective intervention measure of balance’s issues among the people after vigorous exercise. Falling is also associated with vigorous exercises where people experienced poor coordination and imbalance. Effective measure to address these challenges will promote better health and living for the people after exercises. Sway balancing application is considered an effective way to help in determining the level of damage caused by the loss of body balance and coordination that match the aim of this study.

Statement of the Problem

The main goal of clinical balance evaluations are: 1) to recognize whether a balance issue exists and 2) to focus on the fundamental reason for the balance issue if it is due to exercise durations. It is useful to figure out if a balance issue exists so as to anticipate danger of falls and to focus viability of mediation. Balance's testing apparatuses that make a distinction in the balance issue can help to design the kind of mediation for more compelling administration or treatment of the balance issue. In a perfect word, quantitative, standard referenced instruments to survey postural control in the facility ought to incorporate measures that are:

1. sensitive to postural control variations,
2. reliable and legitimate, and
3. Practical, i.e.; simple to utilize and modest.

Research Objectives

To meet the proposed objectives for this research, it is important to evaluate the research questions that will guide the researcher in the project. To facilitate research's objective, it is important to formulate the following research questions in the research process.

1. What is the significance of the treadmill on the body balance?
2. What is the reason why the Sway balance application is preferred for this research?
3. What is the effect of different running durations on balance and recovery that will be tested by the Sway balance application?

These research objectives will facilitate in the answering research questions that are formulated for this research. They will guide the researcher in the research process to ensure that the intended outcome of the study is achieved.

Limitations

The limitations of this research were as follows:

1. Lab sitting.
2. Treadmill is not closed to sway balance measurement area.
3. Sway balance tests cannot be randomized

Delimitations

The delimitations of this research were as follows:

1. The running procedures on the treadmill and sway balance application were measured at Laboratory setting.

2. The subjects have to follow the guiding instruction from Sway Balance Application on the IPhone/IPad devices.
3. The subjects were over 18 years' old students from Barry University.
4. The subjects were free from vestibular, visual problems, or lower limb injuries.
5. The subjects have to wear sport shoes and training suits.
6. The subjects should be free from visual problems, vestibular problems, lack of coordination, dizziness, lower limb injuries, neurological diseases.

Assumptions

This research was followed this assumptions:

1. The subjects were aware of the aim of the study by signing the consent form.
2. The subjects were able to reach 60 to 70 of HR after prolonged running procedures.
3. Sway balance application provided a clear finding that would show high level of imbalance after running procedure.
4. The study were easy to be repeated with different group of people.

Independent Variables

Variables were as follows:

Exercise durations with pre-Sway balance test, post-Sway balance test with 3 levels:

1. Immediately after running procedure.
2. 5 minutes after running procedure.

3. 10 minutes after running procedure.

Dependent Variables

Dependent Variables were as follows:

Sway balance test scores

1. Feet together.
2. Tandem.
3. Semi-tandem.
4. Single leg support.

Operational definitions

- Balance: Body balance is the capacity to keep up the line of gravity of a body inside of the base of the support with negligible postural sway (Paillard, 2012).
- Sway Medical: Is an FDA-cleared balance testing framework which utilizes the assembled as a part of a tri-pivotal accelerometers of a portable electronic gadget to unabashedly evaluate postural development (Alberts, et al., 2013).
- Line of gravity: An imaginary vertical line from center of mass (Paillard, 2012).
- FDA: Food and Drug administration
- Fatigue: Physical fatigue refers to failures that result from recurrent or otherwise varying load that is inadequate to cause an effect when the application only occurred ones. In his definition, Halfpenny, (2010) uses an illustration of a plastic deformation that agrees to the fact that fatigue is not caused by theoretical stresses

realized on conditions that are perfect but instead develop from cracks that already existed and were undetected.

Summary of the Chapter

The various sections of this research have evaluated the scope significance, rationale and purpose of the research. It has emphasized on the analysis of the effect of exercise durations that followed anaerobic exercise on balance. Balance is considered to experience changes when different levels of exercise durations are experienced by a person. At the lower leg, it diminishes the feeling of position and the control of equalization (Rohleder, 2012).

For instance, it is noted that it inspects how plantar flexor and dorsiflexor exhaustion instigated through an isokinetic convention influenced the control of balance. They reported a noteworthy increase in medial-lateral (M-L) body influence motions sufficiency contrasted and a no exhausted state. Understanding an effective intervention measure for people or patients with balancing challenges is crucial. Majority of the people have failed to acquire an effective method for determining how they can understand measures to ensure appropriate use of the Sway balancing application (Rohleder, 2012).

This section has found out that majority of people with balance issues fail to acquire treatment due to high cost associated with the process using other measurement methods. By introducing the treadmill and Sway balancing application, this problem may experience an attractive intervention measure due to low cost associated with the Sway application. It is considered that Sway application is easier than other hard balance equipment to implement in the healthcare sector. To identify contrasts in postural influence obliges an arrangement of measures that can adequately portray the "irregular" oscillatory movements that constitute influence (Patterson, et al., 2011).

The main purpose of understanding of these studies is that numerous measurement are expected to describe postural influence. Investigations of the sensitivities of distinctive influence measures to changes in theorized physiological determinants of postural influence have additionally been few and restricted to some extent. One explanation behind this constrained study is that affectability examinations involve deliberately shifting one variable and watching the subsequent changes in another; the properties of the postural control framework can't be effortlessly controlled in this way tentatively (Patterson, et al., 2011).

To achieve the stated objectives, the research will be aimed at meeting the following objectives in the research process. The purpose of the study is to evaluate the effects of exercise durations on balance and recovery tested by the Sway balance application

Chapter II

Literature Review

1. Balance Control

Balance is an important requisite for the operation of many of our daily living activities ranging from sitting on a chair to reach for an item located in a high cupboard to walking home from a shop bearing a bag of food markets through a crowded street (Lohse & Sherwood, 2011). The mastery of balance is a complex sensorimotor process that requires the consolidation of data from the multiple sensory systems (i.e., visual, vestibular, and somatosensory) to generate appropriate motor responses to maintain an upright position and prevent falling (Lohse & Sherwood, 2011). Specifically, it is a challenging process requiring an individual to control the centre of mass (COM) within the base of support (BOS) whether that BOS is stationary (i.e., as would occur during quiet stance) or moving (i.e., as would occur during walking). The COM can be defined as an imaginary point around which the total body mass is equally distributed (Paillard, 2012).

The BOS can be defined as the area of the body that comes in contact with the environment (i.e., supporting surface on which one stands) and it allows for ground reaction forces to be generated in order to control the movement of the COM (Hoch, Staton & McKeon, 2011). The central nervous system (CNS) must make constant and precise adjustments in order to control the COM within a stationary BOS (i.e., when the COM moves within the BOS when standing) or moving BOS (i.e., when the COM moves outside of the BOS with each step while walking). The centre of pressure (COP) can be defined as the location of the weighted average of the sum of vertical ground reaction forces and most often is examined in the anterior-posterior (A-P) directions and the medial-lateral (M-L) directions. The COP reflects the generation of stabilizing ankle torques (i.e., adjustments in the A-P directions) and lateral weight shifts (i.e., adjustments in the M-L direction) to control the body COM and as such the COP provides an indication of the CNS response to control COM movement.

Many factors have been shown to influence balance control. These factors may be physiological (e.g., reduced lower limb muscle strength; (Wolfson, Judge, Whipple & King 1995), emotional or psychological (Miller & Bird, 1976), or cognitive (Gosselin, Rassoulian & Brown, 2004). Furthermore, interactions between multiple physiological, psychological or cognitive factors can lead to confounding effects on balance control. The effects of these factors can be more pronounced when performing difficult tasks (i.e., one-legged stance, obstacle avoidance, balance recovery) or when performing in challenging environments (i.e., navigating through a cluttered room). One important cognitive factor that has been shown to influence balance control is attention.

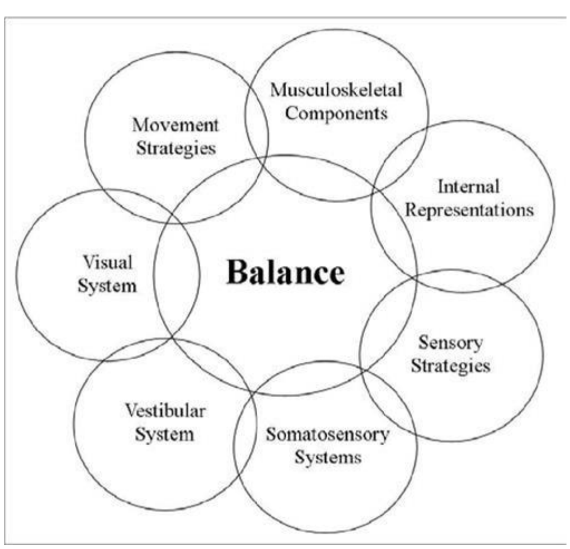
For example, divided attention protocols (i.e., dual-tasks' situations where individuals perform a concurrent task while maintaining balance) have been shown to impact balance control (Lohse, Sherwood & Healy, 2014). Attention focus or "where" an individual directs their attention when completing a task has also been shown to modify balance control (Gosselin, Rassoulian & Brown, 2004). This study will examine exercise focus and its effects on motor skill performance, specifically balance control, and whether instructions related to attention focus can modify the influence of a specific factor (i.e., muscle exhaustion) that has been shown to influence balance control. First, the literature review in this section will concentrate on the effects of exhaustion on motor skill performance, and more specifically balance control. This will be followed by a review of the literature on the effects of muscle exhaustion on balance control in order to demonstrate its efficacy as a model to show balance differences in order to examine whether specific attention focus can minimize these exercise-related effects on balance.

2. Conceptual mechanism of Balance

Balance is a key segment of motor aptitudes, going from keeping up the ability to executing complex game abilities, and is characterized as the capacity to keep up the centre of mass (COM) inside the stationary or moving base of support. It is an unpredictable procedure including coordination of numerous tactile, motor, and biomechanical parts, and can be changed or effected by the task being performed for the body's development, influence, and biomechanics (Davidson et al., 2009). The applied model for the balancing framework hypothesis, including the interfacing mechanism adding to adjustment and introduction.

Figure 1

Balance Framework hypothesis (Davidson, et al., 2009).



The fundamental fuctional goals for the balance system are the maintenance of the specified postural alignment that include the position and the facilitation of the voluntary movement that includes movement transitions that arise between postures . Also the reactions that achieve balance to external disturbances that includes the slip or push (Davidson, et al., 2009).

3. Types of Balance

Balancing utilizes quantifiable data as a part of the type of vestibular, visual, and proprioceptive inputs that is handled by neural structures, which thus deliver a sorted out motor reaction that reflexively restores body balance. It is noted that balance can be categorized into two types: static and dynamic. Static balance is found to take place when balance is kept up for one stationary body position (calm remaining) within the fixed center of gravity (COG), while dynamic balance refer to measuring heading and greatness of weight movement through aggregate vertical power vectors (Horak, 2006). Both static and dynamic balance require coordinating tactile data from the visual, vestibular, and somatosensory frameworks. This framework works as an input control circuit between the cerebrum and the musculoskeletal framework by recognizing insecurity and reacting to the movement of straight increasing speeds and muscle stretch at the lower leg, knee and trunk joints (Edwards, 1981). This internal observations are gotten from the vestibular, visual, and proprioceptive (or somatosensory) sensors transfers summons to the furthest points' muscles which then produce muscular contractions to keep up postural support and solidness (Edwards, 1981).

4.Concept of Treadmill Exercises on Balance and Warming up

Exhaustion modifies the power limit of muscles. It is a complex and diverse phenomenon that include neural and muscular framework. At the lower leg, it diminishes the feeling of position and the control of balance. For instance, Marchant, Greig and Scott (2009) have inspected how plantar-flexors and the dorsi-flexors muscles exhaustion trigger through an isokinetic coordination influenced the control of balance. They reported a huge increase in the mediolateral (M-L) body influence motions contrasted to non-exhausted state. This demonstrates that fatigue has serious consequences for the body systems as it influences the critical aspects of balance.

More worldwide fatigue methods where the weakness is impelled by treadmill strolling or skiing, running or cycling additionally have been utilized. For instance, Bigland-Ritchie, Jones and Woods (1979) utilizing a treadmill aerobic fatigue methods, have reported increase of the influence way of the center of pressure (COP) and middle recurrence of the COP speed after the fatigue procedures. The recent impact proposed the creators that exhaustion triggers an expanded recurrence of activities expected to manage body influence motions. Bigland-Ritchie, Jones and Woods (1979) reported that experienced athletes were less influenced by fatigue proposing that ability could weaken the particular impact of weariness on balance control.

On the other hand, warm-up activities for postural control are a critical variable for typically normal, common individuals and also athletes. Such postural control refer to programmed reactions in the vestibular framework, vision, and proprioception. Poor postural control is connected with diminished dynamic balance. Dynamic balance is the capacity to keep up balance while in movement or to move the body from a static to a dynamic state. Balance disability is a huge risk element for falls among the healthy individuals. Fallings are the main source of death from harm in elderly people (Boyas et al., 2011). In the athletic population, the loss of dynamic balance is a vital component that may bring about harm in game activity. Warm-up activities are light activities that are directed towards a strenuous physical action, which expect to diminish harm, for example, strains and sprains, amid execution. They raise intramuscular temperatures, accordingly enhancing muscle adaptability and improve postural control (Boyas et al., 2011).

Warm-up activities directed before activities or games exercises incorporate stretching, treadmill strolling, and plyometric exercise. Stretching is normally utilized as a warm-up activity to increase the blood flow rates and to avoid muscular injuries. Muscle quality and adaptability are helped by stretching (Boyas et al., 2011). On the other hand, treadmill strolling is a warm-up activity that uses the entire body. It improves oxygen consuming capacity and has a constructive outcome on balancing capacity. Aerobic preparing is a sort of resistance preparing. It can enhance body balance, coordination, readiness, and force, and it has a significant consideration as a warm-up activity to improve physical ability. Aerobic activities utilize fast movement activities to progress concentric muscle activity, reflexive reactions, and practical activity designs. It built lower body’s muscular control, quality, and balance (Chaubert & Paillard, 2012).

5.Effects of Fatigue on Balance Control

There are some different ways to generate muscle fatigue. Research has examined general muscular exercise such as running, cycling, etc. (i.e., exercises typically involving whole body movement) resulting to changes in balance control (Paillard 2012). Research has also examined the effects of lower muscular fatigue (LMF). LMF refers to the fatigue of a specific muscle group and can be considered as "the failure to maintain the required or expected force" or as "any exercise-induced reduction in the capacity to generate force or power output" Chaubert & Paillard (2012). The effects of LMF on balance control have been explored for a range of specific muscle groups (i.e., ankle musculature, hip musculature, lumbar extensors, etc.), fatigue protocols (i.e., isometric contractions, isokinetic contractions, etc.), and balance tasks (i.e., single leg stance, two-legged stance, balance recovery from external perturbations, etc.; Paillard, 2012). This study will examine the effects of LMF on balance control, specifically focusing on LMF of the ankle muscles.

6.Ankle Musculature Fatigue

Investigations into the effects of LMF of the ankle musculature on balance control have employed a wide variety of balance tasks and fatigue protocols. A study shows that fatigue of the plantar-flexors, dorsiflexors, or invertors and evertors results in increased balance adjustments during both single and two-legged stance during dynamic balance tasks such as standing on an unstable support surface and balance recovery following an external perturbation (Gribble & Hertel, 2004a).

Gribble and Hertel (2004) found isometrically induced plantar flexor fatigue resulted in not only increased A-P and M-L velocity and total sway of the COP during single leg stance with both eyes open and closed but also increased M-L amplitude of COP adjustments when the eyes were closed. Gribble and Hertel (2004b) examined the balance effects of exhausted single leg only on single leg stance of the fatigued or non-fatigued leg. They found that following fatigue, stance on either leg resulted in increased M-L & A-P trunk acceleration, A-P amplitude of excursions of the COP, and decreased M-L velocity of the COP. Stance on the fatigued leg also showed increased M-L COP amplitude and decreased A-P velocity of COP movements. In contrast, Marchant et al., (2009) found no effect on COP velocities during single leg stance with vision after isokinetically fatiguing the plantar-flexors.

Marchant et al., (2009) compared the effects of isokinetically fatiguing either the plantar-flexors or dorsiflexors to when both muscle groups were fatigued simultaneously. To examine this, participants completed three separate testing sessions during which they fatigued either the plantar flexors only, dorsiflexors only or both plantar-flexors and dorsiflexors muscles. In each session, the muscle group(s) chosen was fatigued isokinetically until unable to produce 50% of their pre-fatigue peak torque. Following fatigue, balance control was examined through a two-legged stance task with and without vision. The authors found degradations in balance control emerged via increased total sway and A-P velocity of the COP as well as a posterior shift in the average position of the COP following all three fatigue protocols. However, increases were found to be significantly greater in all measures following the simultaneous plantar-flexor and dorsiflexor fatigue compared to fatiguing either muscle group on its own. It’s noted that the decreases in balance control were only observed when the balance was assessed with vision removed. In contrast to these findings, isokinetically induced LMF of the plantar-flexors and dorsiflexors together has shown effects on balance control when vision is present.

Lin et al., (2009) found that consecutively fatiguing the dorsiflexors then plantar-flexors in a blocked format through isokinetically performed concentric-eccentric contractions resulted in increased amplitudes of A-P and M-L movements of the COP. In addition to an anterior shift of the COP when standing on one leg with the eyes open. Lin et al., (2009) added that it simultaneously fatigued the plantar-flexors and dorsiflexors in an isokinetic manner until less than 50% peak torque could be produced in both directions. Following fatigue, increases occurred in the velocity of A-P movements of the COP but not in the M-L direction during single leg stance with eyes open. Dickin & Doan (2008) examined simultaneous isokinetic fatigue of the plantar-flexors and dorsiflexors; however, fatigue was defined as an inability to produce 70% peak torque in both directions. Furthermore, the stance task was performed on both a normal and sway referenced surface. Following fatigue, increases were observed in the amplitude variability of COP movements in both the A-P and M-L directions. These findings were consistent across both surface conditions. Bellew & Fenter (2006) further showed the effects of simultaneous isokinetic fatigue of the plantar flexors and dorsiflexors through decreases in the single leg stance time test and functional reach scores of older women who were fatigued to <50% peak torque in both muscle groups. Poorer scores on both of these measures are interpreted as decreases in balance control.

Conclusion on the effects of LMF of the invertors and evertors during balance control were less clear. Gribble & Hertel (2004) isokinetically fatigued the invertors and evertors simultaneously to <50% peak torque and found no effect on the velocity of COP movements during single-legged stance with vision. Landers et al., (2005) however, found increased M-L and total sway of the COP during single leg stance with vision along with increased A-P sway on a forward lean test following successive isokinetically induced fatigue of the invertors, evertors, dorsiflexors and plantar-flexors to <50% peak torque. It must be noted that the results seen in that study may be due to the fatigue of the plantar-flexors and dorsiflexors rather than the invertors and investors.

Research investigating the effects of LMF of the ankle musculature on balance control during two-legged stances have focused solely on LMF of the plantar-flexors. Kennedy, Guevel and Sveistrup (2012) found that isometrically induced fatigue of the plantar-flexors result in increased velocity and standard deviations of A-P movements of the COP during two-legged stances with eyes open. Bisson et al., (2010) showed similar results in that isometric plantar-flexor fatigue caused increased A-P & M-L velocity of COP movements with the eyes either open or closed, as well as increased total sway area when tested with the eyes open. Kennedy, Guevel and Sveistrup (2012) added that the participants were unable to produce 60% of their MVC when the plantar-flexors of the dominant leg was fatigued via isotonic contractions. When fatigued they found increased COP-COM difference measures in the A-P direction during two-legged stances with the eyes closed. The difference between COP and COM has been found to be highly correlated to horizontal COM movements and could be interpreted as the “error” of the balance control system

Investigations into the effects of LMF of the plantar-flexors on balance control during Tandem stance position have compared the effects of fatigue both with and without vision. Gribble and Hertel (2004) found that isometrically fatiguing the plantar-flexors by requiring participants to rise to their toes and hold this position as long as possible resulted in increases in the A-P sway amplitude as well as A-P and M-L sway velocities of the COP with eyes either open or closed. Gokeler et al., (2014) also found no interaction between LMF of the plantar-flexors elicited via 100 weighted heel raises and visual conditions. Their results demonstrated increases in mean A-P and M-L sway velocity, maximum instantaneous A-P sway velocity, and mean and median frequency of sway of the COP regardless of the availability of visual information.

Other studies have looked at the effect of LMF of the ankle musculature on balance control during dynamic balance tasks. Nardone and Schieppati, (2010) fatigued either the plantarflexors or dorsiflexors through weighted concentric-eccentric contractions to volitional fatigue and found no effect of either protocol on time spent in balance (i.e., horizontal) on an unstable support surface during subsequent 60 seconds trials. However Rand et al., (2011) using an unstable platform found that simultaneous isokinetic fatigue of the plantar-flexors and dorsiflexors to less than 50% peak torque resulted in increased deviations from the horizontal position of the platform which characterized as poorer balance performance.

Tanriverdi, Unluhizarci and Kelestimur (2010) found increased A-P, M-L, and overall deviations on an unstable platform to arise following weighted calf raises. Similar results were found by Rand et al., (2011) following simultaneous isokinetic fatigue of the plantar-flexors and dorsiflexors or invertors and evertors. However, Salavati et al. (2007) found that combined invertor and ever to fatigue created significantly larger increases in the M-L direction compared to combined plantar flexor and dorsiflexor fatigue. When compared to unperturbed stance, limited research has been conducted to investigate the effects of LMF on balance recovery following external perturbations. The research that has been conducted has shown some significant changes in balance recovery strategies and muscle activation patterns when fatigued.

Zimmer et al., (2011) simultaneously fatigued the plantar-flexors and dorsiflexors of participants through alternating isometric contractions until both muscles were unable to produce 50% MVC. Following this, participants were required to stand with feet shoulder width apart and eyes open on a perturbation platform that oscillated 20 cm in the A-P direction at a frequency of 0.25-0.5 Hz. Following the fatigue protocol, increased co-activation of the tibialis anterior and medial gastrocnemius were observed. Additionally, during forward perturbations the tibialis anterior and rectus femoris were activated earlier. Upon examination of reactions during backward perturbations, two subgroups emerged. The first was characterized by an increase in the amplitude of displacements of the COP with an accompanying decrease in biceps femoris activity. The second group exhibited a decrease in the amplitude of displacement of the COP along with earlier medial gastrocnemius onset times and higher levels of tibialis anterior – medial gastrocnemius co-activation compared to the COP increase subgroup. Hubbard et al., (2011) investigated the effect of LMF of the plantar-flexors on balance recovery to forward external perturbations in both young and older adults. LMF was elicited using concentric weighted contractions of the plantar-flexors until <70% MVC could be produced. Fatigue was found to cause increases in peak amplitude and velocity of the displacement of the COM, and decreased amplitude of displacements of the COP in both groups. Additionally the older group was found to have an increased time to return within 20% of the peak COP displacement following perturbation which can be interpreted as a slower recovery rate to the perturbation.

7. The Impact of fatigue on Balance

Marchant et al., (2011) conducted a study whose main objective was to inspect the impacts of fatigue of the lower limb for postural control amid single-leg position. Fourteen healthy volunteers (age, 21-23 years) with no history of lower-limb damage or neurologic deficiencies were incorporated into the study. Testing comprised of isokinetically exhausting the sagittal plane movers of the lower leg, knee or hip with measures of static postural control. Postural control was connected with three 30-second trials amid one-sided position with eyes open. Result measures utilized were, center of pressure excursion velocity (COPV) in the frontal and sagittal planes. Results exhibited exhaustion at the knee and hip which prompted postural control disability in the frontal plane, while fatigue at the lower leg did not. In the sagittal plane, weakness at all 3 joints added to postural control barriers. Researchers identified that there is an impact of restricted weakness of the sagittal plane movers of the lower furthest point on COPV. It gives the idea that weakness of the hip and knees joints had a more noteworthy unfavorable impact on COPV.

8. Duration and Recovery from Fatigue Effects

An important factor that must be taken into consideration when examining the effects of LMF on balance control is the time course of the effects of exercise on balance control. Recovery rates from the exercise protocol and thus the disturbance to balance can vary widely depending on the nature of the exercise protocol. For example; the duration of the exercise protocol, the muscles fatigued and their corresponding muscle fiber composition, the nature of the muscle actions performed to elicit fatigue (i.e., concentric compared to eccentric), and the percentage of strength loss that was induced, can all affect the time course of resulting balance disturbances (Paillard 2012). Taking this into consideration, the resulting disturbance to balance following LMF has been found to persist from 2 minutes (Boyas et al., 2011) to 30 minutes (Dickin & Doan., 2008) following the completion of the exercise protocol depending on the specific protocol used. Given the time course of exercise effects on balance control, most studies have aimed to perform post exhaustion postural evaluations as soon as possible following the exercise protocol (i.e. 30-60 seconds; Boyas et al., 2011). Alternatively, some studies that examine multiple attempts of balance trials post exhaustion repeated the exercise protocol before each trial or set of balance trials to ensure that the appropriate fatigue level was present at the time of each measurement (Boyas et al. 2011). Regarding rest, Willardson (2008) indicated that rests duration between activities is affected by several elements and he stated that the rest period in muscular endurance exercise is ranged from 30 to 90 seconds.

On the other hand, recovery from the activity is a necessary part of the general preparing program. Recovery is an important part of the performance and for designing effective programs. It is defined as the capacity to meet or exceed performance in a specific actions (Bishop et al, 2007). Jeffreys (2005) suggested that recovery can be determined by the following; restoring of physiological functions (e.g., cardiac circulation, heart rate, normal blood pressure, normal breathing rhythm), normalization of energy stores (blood glucose and muscle glycogen), and return to homeostasis of the electrical activities at the level of cell. Muscle recovery happened basically after activity and is described by proceeded with decrease of metabolic products such as accumulation of lactic acid. After activity, recovery is expected to restore and to oxygenate intra-muscular blood supply which advances refreshing of the phosphocreatine stores, rebuilding of intra-muscular pH, balancing of the electrical activities (Weiss, 1991). Other physiological aspects of recovery is to restore normal ventilation, equal disruption of blood supply to different body parts and restore body temperature to baseline (pre-exercise levels) (Borsheim and Bahr, 2003).

Recovery from exercise can be categorized into many form; Immediate recovery, training recovery and short recovery. Immediate recovery is the fastest one in recovery and usually occur within seconds or during training while training recovery required to be within workout sessions. Without training recovery, athlete or trained individual will not be ready for the following session (Bishop et al, 2007). The third type of recovery short term recovery is the most popular form of recovery because it is usually happened between exercise’s sets (Seiler, 2005).

There are many factors must be taken in consideration that enable the trained individual to recover such as muscle weakness, poor training protocol, infection, inflammation, and lack of sleep. Those factors might have a negative impact on individual abilities to recover from training (Gleeson, 2002). Additionally, Jeffreys (2005) states that individual differences might exist within the recovery procedure due to individual physical status (trained vs. untrained), fatigue factors and ability of the individual to deal with different forms of stress.

9. Balance Assessment Methods

Balancing assessment is basic for precisely deciding an individual's postural dependability. To assess postural balance, standard, high quality assessments are produced to give legitimate and reproducible results. Many tests have been produced for estimations of standing balance. A basic unipedal static balancing test is broadly utilized and approved technique to quantify standing balance such as the one-leg standing balance test (Gimmon et al., 2011). The one-leg standing test is a period measured test where an individual stands on one leg with eyes closed, the other leg somewhat flexed, and each handheld on the inverse shoulder. For estimation among a dynamic adjusting circumstance, many bearing adjustment test is regularly controlled. One of them is the Star Excursion Balance Test (SEBT). The SEBT includes having a member keep up a base of support with one leg at the center of the star while maximally trying to reach the diverse headings of the star by using the other leg. Another device is used such as foam tilting board, have been utilized to modify the proprioceptive input of the support surface in evaluating dynamic balance (Hutchinson & Tenenbaum, 2007).

Late innovative advancments in hardware and information transfers have given significantly more available quantitative techniques for surveying both static and dynamic balance through accelerometers in cell phones (Lafond, Duarte & Prince, 2004). Accelerometers were proposed in the 1950's, and have advanced innovatively to give adequate high quality with coupled attributes of high-volume and minimal effort generation and take into consideration the quantitative and compact evaluation of human headway and development issue. Accelerometers measure both static and dynamic increasing speed, comprising of moveable bar suspended on micromachined springs that give resistance against the quickening. Avoidance of this bar is then changed over into an increasing speed (G-powers). Three accelerometers can be fused into a single device giving data on three-dimensional development (triaxial accelerometer) (Gabriel, Basford & An, 2001).

The force plate and the accelerometers are both viewed as profitable for measuring the capacity to control or measure balance, despite the fact that they can be relied upon to quantify distinctive parts of balance. It can be addressed to measure different types of balance and it may give same balance scores (Adlerton et al, 2003).Accelerometers are a perfect decision for assessing variability of development and balancing giving a non-intrusive, compact strategy for estimation. Balance assessment utilizing accelerometers has been contrasted and exhaustive clinical balancing evaluations, (for example, Romberg's test, heel-toe straight line strolling, and practical achieve test). Both of these studies purpose that accelerometers are helpful for surveying balancing and that they recognize distinct variations (Gabriel, 2000).

10.Validation of Accelerometers in Balance Assessment

In spite of the fact that there is restricted data on the legitimacy and dependability of accelerometers as devices for balancing evaluation, the present writing demonstrates that accelerometer can give exact and solid measures of essential temporospatial step parameters and segmental increasing velocities of the body when strolling. In this way giving valuable bits of knowledge into the engine control of ordinary strolling, age-related contrasts with dynamic postural adjustment, a gait designs in individuals with a developmental issue. The utilization of accelerometers in cell phones is progressing (Chiviacowsky, Wulf G & Wally, 2010). The idea of a remote accelerometer framework for measuring the characteristics of stride and adjust have been delineated through the G-link® Wireless. Accelerometer Node and Apple iPod and iPhone created by Apple company are contained a three-dimensional accelerometer and have the ability to store measurement information tests.

The latest cell phone applications for evaluating balancing, breakdown the change of increasing velocities rather than increasing speeds themselves. The size of the progressions of body increasing velocities, freely from the sensor introduction or any assessments for gravitational speeding up (Chiviacowsky, Wulf G & Wally, 2010). Given two successive increasing speeds, the distinction vector can be figured. Expecting that the introduction has not changed in this time, the gravitational segment is the same in both time steps, and they are offset, giving the distinction of body increasing velocities without knowing gravitational speeding up.

Study has demonstrate that the iPod and iPhone exhibit the ability to gain precisely evaluated balancing parameters with an adequate level of consistency. Then again, further studies are expected to keep on accepting the precision and dependability of accelerometric cell phones. Besides, there is a need to accept the precision and hight quality of cell phone applications using accelerometry.

Additionally, Amick et al (2015) illustrated that SWAY balance scores provide significant general reliability but it may be more convenient to have individual doing some familiarization trials toward the start of every testing session. Jensen et al (2014) studied the differences between Sway balance scores and BESS balance assessment scores for the older population. He found a significant negative correlation between the scores of both BESS and Sway ($r = -0.640$, $p < .01$). The motivation behind this study is location the balance evaluation measures from a cell phone application (iPod) using accelerometric movement sensors against the balance assessment measures of a clinically valid and reliable testing of balance (BIODEX Balance System SD) (Davidson, Madigan & Nussbaum, 2004).

11. Fall and Injury Risks due to Poor Balancing

Different components are assumed to be a part in falls and injuries mechanisms, however, poor balance is the dominant reason for falls in older people and injury in athletes. Human balance depending on the collaboration of the sense of vision, touch, and so forth. In addition to the capacity to control the change of our bodies. These capacities decrease essentially with aging, which can prompt falls when there are no identifiable neurological or musculoskeletal issues. Falls are the main source of the injury-related deaths and hospitalization in individuals matured 65 years and over. No less than 40% of individuals who have been hospitalized due to a fall require ensuring consideration in a nursing home. A further 10% need progressing help at home from group services. The rate of falling in more established individuals living in nursing homes is much higher, with different studies reporting fall rates of somewhere around 40% and 56% in elderly occupants every year (Wulf, et al., 2010).

There are various acknowledged definitions for falls. However these concur that in the case of a fall the individual goes to a lower level or on the ground unintentionally. The World Health Organization (WHO) recognizes a fall as one of the outer reasons for unexpected injury. It is coded as E880-E888 in the International Classification of Disease-9 (ICD-9) and as W00-W19 in ICD-10 (Bizid et al., 2009). Roughly one in three more established individuals fall every year; this extent fluctuates from locale to district far and wide. The fall rate is some place above 30% in the developed nations, 31% in China, 20% in Japan, 34% in Chile, 29% in Brazil, and 24% in Cuba (Bellew & Fenter, 2006). There is no epidemiological report for Africa, South Asia, and the WHO Eastern Mediterranean region.

However, information are lost from a few sections of the world, it is clear that falls are a noteworthy wellbeing issue among the elderly, mortality, and cost. Understanding the concepts of balance as a prevention strategy for falls is a critical insight into the protection of people experiencing challenges in the balance. It is considered that balancing require the individuals to be aware of their status that would help them in seeking medical attention to their condition prevention the occurrence of falls and injuries (Bellew & Fenter, 2006).

Also, Bisson et al., (2010) noted that falls are thought to be a consequence of collaborations between numerous elements, for example, lessened vision, debilitations in somatosensory capacity, lower appendage muscle shortcoming, and diminished mobility. Fallers demonstrate a critical decrease in muscles around the knees and lower leg joints when contrasted with more stable grown-ups without a fall history. Gait, balancing issue, or shortcoming has been recognized as the second driving reason for falls in the elderly, and the balance shortfall is the second driving danger variable for falls.

Typical postural control or adjust is reliant on the ordinary integrative working of body mechanism, for example, somatosensory inputs, vision, and motor frameworks. Balance is concerned fundamentally with looking after, accomplishing, or revising the center of gravity in connection to the base of support (BOS). Balance assumes a vital part in portability and additionally security, despite the fact that adjust, or postural control relies on upon the cooperation between various frameworks (Caron, 2003). With aging, the postural control system turns out to be less effective as a result of changes in individual's segments.

It is reported that decreased firing sensation, muscle shortcoming, and expanded response time are noteworthy contributing components to postural balance in the elderly. Likewise, it is reported that more seasoned grown-ups with the impediment of vision and those in whom somatosensory inputs from lower leg joint region were restricted. In postural influence investigation, it was accounted for that more established grown-ups had expanded influence among controlled somatosensory capacity testing (Bizid et al., 2009). Another part of postural control instrument is the integrative handling, which might some way or another be known as tactile association, where an individual needs to prepare the data for the proper reaction. In more established individuals, the focal integrative preparing is influenced as there is an increment in response time in the event of a presentation of tactile inputs. Another range of concern is that the elderly have restricted abilities in double tasking, as examinations have demonstrated that the balance control of more seasoned grown-ups is influenced by performance when contrasted with more youthful adults (Zachry et al., 2005).

12. Gaps in the Review of Literature

It is acknowledged that there exist limitations in the previous studies conducted. First and foremost the results of this review are only generalizable to healthy young adults as it focused on the effect of fatigue on healthy young population. However, much of the existing literature (Chapter II) provides information based on effect of fatigue on balance for old individuals or for patients with different complications with the majority of the studies observed older adults or individuals with neurological or musculoskeletal deficits. Likewise the results contained herein are only generalizable to the specific fatigue protocol used to elicit localized muscular fatigue of the ankle plantar-flexors (i.e., heel raises). A lack of standardization of fatigue protocols has been acknowledged as a limiting factor in comparing between different studies examining the effects of localized fatigue on balance (Corbeil et al., 2003). Furthermore as the results observed may be dependent on constraints imposed specific to the balance task examined, the results are only generalizable to the type of balance task explored in this research. The results may not apply to the provision and use of different attention focus instructional sets. Several assumptions have been made in the previous researches that may also serve as limitations.

Literature review examined has assumed that participants would adhere to the balancing challenges in close reflection to the benefit of balance performance. The results may have been influenced by individuals not adhering to the attention focus instructional sets. An additional assumption that was made was that maximal effort was put forth by participants during the fatigue protocol. Additionally, other previous researches have analyzed the fatigue protocol that was terminated when participants reported they no longer could or were unable to continue. As such the assumption was made that the participants were actually fatigued and if they were, it was to the same level within the three different attention focus groups (Cetin et al., 2008).

The literature review observed are limited to the balance related measures that were collected (trunk pitch and roll sway, amplitude variability of the tilt-board, and EMG of the lower leg muscles, TA and MG). Other balance measures that could have be examined (i.e., whole-body COM, joint angles, upper leg and trunk EMG) may have resulted in different effects of instruction in reducing fatigue effects on balance and provide additional insight into the strategy used to maintain balance under conditions of a fatigued state and instructional sets (Adlerton, Moritz & Moe-Nilssen, 2003).

Chapter III

Methods

Participants

30 participants _9 female and 21 males_, 18 years and older, were recruited at Barry University via flyer. Anthropometric measurements are presented in Table 1. The participants were free at least for one year from any sign of dizziness, vestibular problems, visual problems, lack of coordination due to neurological diseases, lower limb injuries, limb length discrepancy and pain that measured by visual analogue scale (VAS). All participants read and signed a written informed consent form in which they informed of the aim and the characteristics of the study. They also signed a questionnaire to see if they meet the inclusion criteria. All experimental procedures were approved by the Institutional Review Board and Ethical Committee of Barry University.

Table 1
Anthropometric measurements of the subjects

	Age (years)	Weight (kg)	Height (cm)
Male Subjects	30 y/o, SD= 3	69 kg, SD = 7	176cm, SD =0.18
Female Subjects	31y/o, SD =3	60kg, SD =9.2	164cm, SD = 15

Note: SD= Standard deviation.

Instrumentation

The experiment trials were performed at Barry University's Human performance lab. ***Treadmill*** trackmaster manufactured by Full Vision, the model USA 2015 was used for the exercise protocol. ***Sway Balance Application*** (Sway Balance TM System _ Korebalance TM by SPORTKAT, LLC K070676) a mobile measurement system analyzed balance through thoracic swaying, using the built in accelerometer of a mobile device. It is a software only solutions that utilizes the hardware of the Apple iOS mobile operating system. The built in accelerometer is accessed to analyze motion during a balance test. ***Modified Borg scale*** of Perceived Exertion (Grant Et al, 1999) was provided frequently for the participants to measure the level of exertion during the running procedure (Figure1). This scale was created by Gunnar Borg and it is a commonly used to determine exercise intensity levels. Also, it shows the training sessions intensity. The original Borg scale is ranged from 6 to 20 as seen Rating of perceived exertion Borg scale (see below). Even though it is subjective way of measurement, it is indicate how someone feel about their level of effort and exertion. The perfect training zone for normal healthy adult is ranged from 12 to16 on the Borg scale, and this is approximately equal to 60 to 80% of the target heart rate. This targeted zone allows to get the maximum benefit of cardio respiratory training. On the other hand, training from 17 to 20 on the Borg scale is not suggested and should be avoided .Borg scale (RPE) should be taken during the undertaking the training and to periodically ask the participant to rate the perceived exertion for a given exercise.

Figure 2

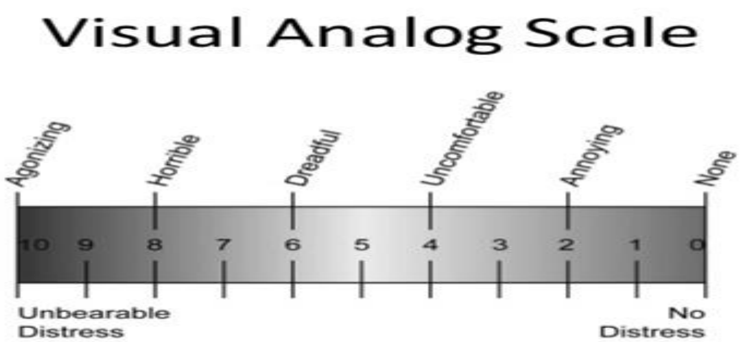
Rate of perceived exertion (RPE) scale used to indicate level of fatigue.

Rating of Perceived Exertion Borg RPE Scale		
6 7 8 9 10 11	 Very, very light Very light Fairly light	How you feel when lying in bed or sitting in a chair relaxed. Little or no effort.
12 13 14 15 16	 Somewhat hard Hard 	Target range: How you should feel with exercise or activity.
17 18 19 20	Very hard Very, very hard Maximum exertion	How you felt with the hardest work you have ever done. Don't work this hard!

Leg Length discrepancy test is to compare if there is real difference between the right and left lower limbs by using Tape Measurement from the anterior superior iliac supine to medial malleolus to compare the right and left lower limb. The leg length discrepancy should within 2 cm or less to be accepted for the study. Also, Visual Analog Scale (VAS) will be included to measure the level of the pain by using VAS chart (see below). For pain intensity, the scale is commonly anchored by “no pain” (score of 0) and “worst pain ” (score of 10).

Figure 3

Visual Analog Scale



The resting heart rates were collected from each participant in order to measure the target heart rate during exercise. The target heart rate should be within zone 1 which is 60% to 70% of the maximum heart rate that represents the optimal heart rate during the physical activities according to American college of sport medicine ACSM (see Table 2) and it was be monitored through ***heart rate monitor*** (Monark, Swedan). ***Gym's mats*** and ***emergency belt*** were used for participants at Human Performance Lab and Wellness center.***Gym's mate*** was available and surrounding the treadmill from each side that's aim to protect the participant from any possible falling risk.

Table 2
Target Heart Rate calculation.

Target Heart Rate	[(percentage) X (220 – participant age)]
	• The percentage should represent Zone1 (60% to 70%). • 220 represent the estimated maximum heart rate by American Heart association.

Procedures

The experiments were held at Human Performance Lab at Barry University. All the students were able to see the posted flyers at Barry University about their participation in this study. After the random selection, they informed of the aim of the study and they were given a questionnaire form about the participants' age, height, weight, and their medical conditions. This personal information were entered anonymously in Sway balance website to create a special file for each student. Additionally, they signed the consent form provided by the investigator and the investigator signed as well. They were reminded to wear sport shoes and suitable clothing for running.

Later, the participants were assigned into 3 different groups: 20 minutes running group, 30 minutes running group, and no running group (control group). All the participants were receiving the same and exact Sway balance testing.

Balance protocol

The entire protocol for each participant was approximately 40 to 50 minutes and each protocol was composed of the following: Step 1 Sway balance tests (A) as a baseline, Running procedures on the treadmill, Step 2 Sway balance tests (B) immediately after the running procedure on the treadmill, Step 3 Sway balance tests (C) after 5 minutes from the running on the treadmill, and Step 4 Sway tests (D) after 10 minutes from the running on the treadmill.

The Sway balance test was repeated four times: one before the running procedure and three after. The Sway balance tests included four tasks: 1) Feet together with closed eyes,

2) Semi tandem with closed eyes, 3) Tandem with closed eyes, and 4) Single leg supported with closed eyes. The detailed instructions in those tests were visually or auditory provided by Sway balance application as pictures and the participants were able to follow the exact steps. Those tests needed to be addressed in specific time without any distraction from the surrounding environment. (See Figure 4)

Figure 4

Sway balance application Protocol.

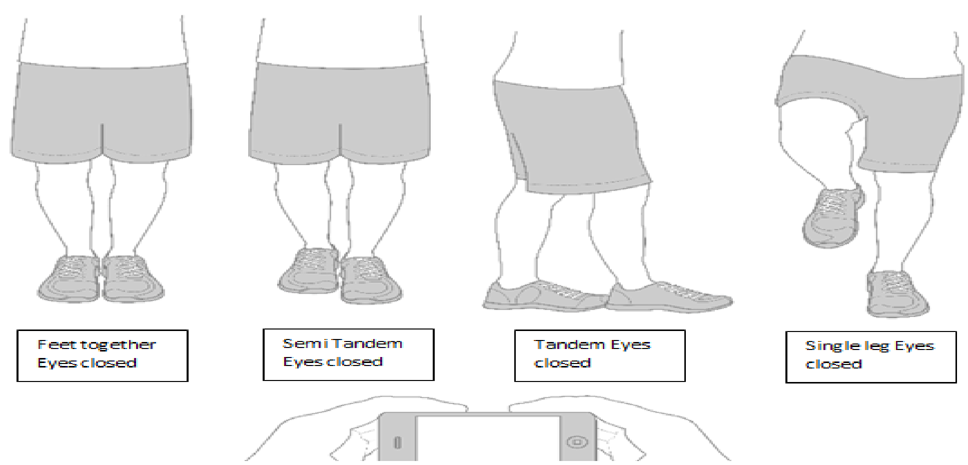


Figure 5

The Foot placements of the following tests; Feet together, Semi-tandem, and full Tandem or (Tandem)

Running protocol

Each participant was required to run on the treadmill for 5 minutes with speed of 3.5 Mph to warm up faster and to get ready for the experiment. Then, the participants were running according to their group classification as 20 minutes of running, or 30 minutes of running or no running at all (control group). The running speed started with self-selected speed (Mph) during the running procedure, the participants were asked frequently by the instructor to indicate their level of exertion by using RPE Borg scale and to monitor their personal target heart rate.

Heart rate equation was used for each individual [220 – age = Heart rate]. Then, the result was multiplied by 60% and 70% to indicate the low end and high end zones. The participant's heart rate was monitored between 60%- 70% of their maximum heart rate by increase or decrease the speed accordingly. The HR was monitored through the chest strap monitor and Borg scale. The running procedure will be stopped immediately if the participant is not able to continue the running task, or if he/she reached the number 20 on the Borg scales, or exceeded the heart rate, or upon his/her request, noticeable change in heart rhythm (see table 3).

To clarify the running procedure, the participants were warming up until they reach 60% of their maximum heart rate based on HR strap monitor. Then they started their self-selected speed running. If their heart rate goes beyond 70%, then the treadmill speed will be decreased or if their heart rate less than 60%, the treadmill speed will be increased. Since there are individual differences between participants, the investigator had to remind each participant to monitor heart rate and to insure that the HR is between 60% to 70%.

Table 3
Each subject have to follow this instructional steps.

First Step	Sway balance application first test	Before the running on the treadmill (baseline)	• Feet together test • Tandem test • Semi tandem test • Single leg support (see Figure 4)
Second Step	Warm up + Running procedure on the treadmill	Running on treadmill (20 / 30 / no run) *(Self-selecting speed Mph)*	
Third step	Sway balance application second test	After the running on the treadmill (immediately)	• Feet together test • Tandem test • Semi tandem test • Single leg support
Fourth step	Sway balance application third test	After the running on the treadmill (5 minutes later)	• Feet together test • Tandem test • Semi tandem test

			• Single leg support
Fifth step	Sway balance application fourth test	After the running on the treadmill (10 minutes later)	• Feet together test • Tandem test • Semi tandem test • Single leg support

Data Analysis

Statistical analysis were performed using Statistical Package for Social Sciences Software (SPSS) (SPSS Inc, Chicago IL). The Sway balance scores (for feet together test, tandem test, Semi-tandem test, and single leg support test) were available in Sway balance website for each participant profile and it can be accessed only by using Sway ID and password that provided by the company of Sway balance application. Statistical analysis were performed according to the following methods.

The main hypothesis in this study is to determine the effect of exercise duration and recovery on balance, the effect of exercise duration on Sway balance scores. This hypothesis were tested through a repeated measure MANOVA test with the independent variable of exercise durations with pre sway test and post sway tests with 3 levels (immediately after running procedure, after 5 minutes, after 10 minutes) and the dependent variables of Sway balance test scores (Feet together, Tandem, Semi-tandem, and Single leg support). These varied Sway balance scores will determine if there is any difference in balance at several point post exercise that will result from running on treadmill. The level of significance that used in this study is 0.05. The average of the collected data was used and it is confidentially stored .

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Manuscript

EFFECT OF TREADMILL EXERCISE DURATIONS ON BALANCE ABILITY MEASURED BY SWAY BALANCE APPLICATION.

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Abstract

Study design: Controlled laboratory study, repeated measure design**. Purpose**: to investigate the effect of exercise durations that followed treadmill on the body balance by using Sway balance application. **Background:** large portion of the population over the World experiences loss of balance after exercise and this lead to serious health challenges if it is not addressed on time. It is important to have an inexpensive and easy to use measuring instrument that can take into account the relevant measurements that should be used in determining the effect that activities may lead to loss of balance. On the other side, weakness modifies the power limit of muscles and diminishes the feeling of position and the control of balance. **Participants and procedures**: 30 participants with no history of visual, vestibular, neurological problems were recruited to perform running procedure on the treadmill with different durations(no running, 20 minutes of running, 30 minutes of running). Their balance tests were measured for 4 times; 1 time before the running procedure and 3 times after. Each balance test consisted of Feet together test, Tandem, Semi-tandem, and Single leg support. Each test was done with closed eyes. The balance scores was obtained by using Sway balance application. **Result**: There were no significant difference between Feet together and Tandem. However, there were a significant differences with Semi tandem position after 5 minutes from the running procedure (within subject) $\chi 2(2) = 8.567$, $p = 0.014$ and Single leg support only with 20 minute group (between subjects) $\chi 2(3) = 10.733$, $p = 0.013$. **Conclusion**: no significant difference with Feet Together and Tandem. However, there is significant difference with Semi-Tandem after 5 minutes and Single leg support with 20 minute group **Key words**: Exercise, balance, Sway, treadmill, fall.

Introduction

It is noted that approximately 33% to 50% of a large portion of the population over the World experiences loss of balance after exercise (Whitney et al., 2011). The many-sided quality of control of balance results in a wide-range of balance issues that need orderly clinical evaluation for viable treatment. Much of the existing literature provides information based on effect of fatigue on balance for old individuals or for patients with different complications with the majority of the studies observed older adults or individuals with neurological or musculoskeletal deficits. However, there are few studies that studied the effect of exercising on balance for recreational population.

Loss of balance may lead to serious health challenges if it is not addressed on time. This prevents the accessibility of health services for intervening on poor coordination and loss of balance issues. The Sway Balance Application, which is based on accelerometric measurement of sway, offers an inexpensive and efficient alternative for quantifying posture control and provides excellent opportunities for on-line sway analyses (Boveet al., 2007). The method is reliable and can be used together with clinical balance and mobility tests in various circumstances, particularly in outcome and screening studies (Boveet al., 2007).

Balance is accomplished by incorporation and coordination of different body frameworks, including the vestibular, visual, auditory, and with the extensive contribution of visual spatial frameworks. Data from tactile frameworks is translated into the central nervous systems (CNS) in light of an inner body mapping. The relevant response is processed and communicated to the postural muscle to perform the head, eye, trunk, and appendage developments to look after stance. In order to maintain balance, it is required to accomplish the body center of mass (COM) with respect to the base of support (Boveet al., 2007).

In Biomechanics, the body balance is the capacity to keep up the line of gravity (vertical line from center of mass) of a body inside of the base of the support with negligible postural sway. Some of the activities considered as minor such as breathing, moving body weight from one foot to the next or from forefoot to rear foot or response to outside stimuli such as visual contortions and floor interpretations often necessitate a precise response. An increase in influence is mostly a marker of diminished sensorimotor control and less a measure of deviations (Paillard, 2012).

Alberts et al. (2013) noted that the Sway Balance is an FDA-cleared balance testing framework which utilizes the assembled part of a tri-pivotal accelerometers of a portable electronic gadget to trustily evaluate postural development. The framework was intended to give a method for quantitative balance evaluation in clinical and on-field situations. Human balance is a general term used to depict the coordination of complex tactile and biomechanical procedures with the end goal of keeping up one's center of mass (COM) on their base of support (BOS). The capacity to look after balance or postural dependability is a crucial segment that goes beyond facilitating an upward stance to allowing the performance of complex tasks. Balance enhancement has been indicated to help with recuperation from harm, damage aversion, and improved practical execution in both adults and elderly people. All things considered, the capacity to rapidly and dependably survey balance for any populace, in any clinic, gym, or health setting is turning out to be progressively critical.

Hrysomallis (2011) explained that weakness modifies the power limit of muscles. There are complex and unpredictable neural components involved in this process. At the lower leg, it diminishes the feeling of position and the control of balance. For instance, previous researchers (e.g. Hrysomallis, 2011; Jorgensen, 2012) have inspected how plantar flexor and dorsiflexor exhaustion impelled through an isokinetic convention influenced the control of balance. Jorgensen (2012) and Hrysomallis (2011) noted that a significant increase in mediaolateral (M-L) body influence the extent of motions particularly during the exhausted state.

More worldwide fatigue methods where fatigue is affected by treadmill strolling or skiing, running or cycling likewise have been utilized. Conventions that utilize a vigorous training have reported increase in the center of pressure (CP) and middle recurrence of the CP speed. The last impact recommended by the creators is that exhaustion increases the body’s capacity to cope with the influence of motion (Hrysomallis, 2011).

Exhaustion after vigorous exercises is considered to influence the body balance in an individual. However, the level of stability after exercises depends on other factors, such as body weight, length of the exercises and type of activity engaged (Hrysomallis, 2011). It is important to have an inexpensive and easy to use measuring instrument that can take into account the relevant measurements that should be used in determining the effect that activities may lead to loss of balance.

Jorgensen (2012) reports a decrease in performance in a double task condition (diminished power generation and increased reaction time) contrasted with the single task. Jorgensen (2012) recommended that the double tasks condition forced a 100%

workload on the subject's constrained attention requests. However, Jorgensen (2012) did not identify additional factors that can be associated with the expanded capacity to manage motion after exhaustion. Comparative intuitive procedures in the middle of insight and the balance control instruments have been proposed. For example, attentional requests are more prominent for unsteady than for stable balanced conditions.

This research will investigate the effect of exercise durations that followed treadmill running on the body balance by using Sway balance application.

Methods

Participants

Thirty voluntary subjects were recruited from Barry university via flyer. They were 9 female participants and 21 male participants. The participants were free at least for one year from any sign of dizziness, vestibular problems, visual problems, lack of coordination due to neurological diseases such as Ataxia and Parkinson disease, lower limb injuries, limb length discrepancy and pain that measured by visual analogue scale (VAS). All participants read and signed a written informed consent form in which they were informed of the aim and the characteristics of the study. They also signed questionnaire to see if they meet the inclusion criteria and eligible for participation. All experimental procedures will be approved by the Institutional Review Board and Ethical Committee of Barry University

Table 1
Anthropometric measurements of the subjects

	Age (years)	Weight (kg)	Height (cm)
Male Subjects	30 y/o, SD= 3	69 kg, SD = 7	176cm, SD =0.18
Female Subjects	31y/o, SD =3	60kg, SD =9.2	164cm, SD = 15

Note: SD= Standard deviation.

.Instrumentation

The experiment trials were performed at Barry University's Human performance lab. ***Treadmill*** trackmaster manufactured by Full Vision, the model USA 2015 were used for the exercise protocol. ***Sway Balance Application*** (Sway Balance TM System _ Korebalance TM by SPORTKAT, LLC K070676). It is a mobile measurement system that analyzes balance through thoracic swaying, using the built in accelerometer of a mobile device. It is a software only solutions that utilizes the hardware of the Apple iOS mobile operating system. The built in accelerometer is accessed to analyze motion during a balance test. ***Modified Borg scale*** of Perceived Exertion (Grant Et al, 1999) were provided frequently for the participants to measure the level of exertion during the running procedure (Figure1). This scale was created by Gunnar Borg and it is a commonly used to determine exercise intensity levels. Also, it shows the training sessions intensity. The original Borg scale is ranged from 6 to 20 as seen Rating of perceived exertion Borg scale (see below). Even though it is subjective way of measurement, it is indicate how someone feel about their level of effort and exertion. The perfect training zone for normal healthy adult is ranged from 12 to16 on the Borg scale, and this is approximately equal to 60 to 80% of the target heart rate. This targeted zone allows to get the maximum benefit of cardio respiratory training. On the other hand, training from 17 to 20 on the Borg scale is not suggested and should be avoided .Borg scale (RPE) should be taken during the undertaking the training and to periodically ask the participant to rate the perceived exertion for a given exercise.

Figure 1

Rate of perceived exertion (RPE) scale used to indicate the level of fatigue.

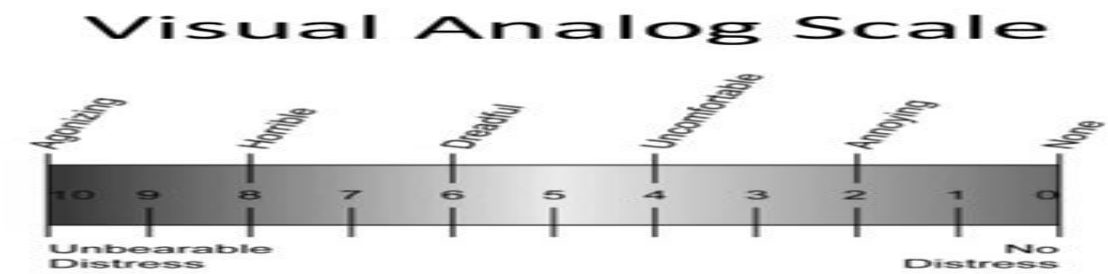
Rating of Perceived Exertion
Borg RPE Scale

6 7 8 9 10 11	Very, very light Very light Fairly light	How you feel when lying in bed or sitting in a chair relaxed. Little or no effort.
12 13 14 15 16	Somewhat hard Hard	Target range: How you should feel with exercise or activity.
17 18 19 20	Very hard Very, very hard Maximum exertion	How you felt with the hardest work you have ever done. Don't work this hard!

Leg Length discrepancy test is to compare if there is real difference between the right and left lower limbs by using Tape Measurement from the anterior superior iliac supine to medial malleolus to compare the right and left lower limb. The leg length discrepancy should within 2 cm or less to be accepted for the study. Also, Visual Analog Scale (VAS) were included to measure the level of the pain by using VAS chart (see below). For pain intensity, the scale is commonly anchored by “no pain” (score of 0) and “worst pain ” (score of 10).

Figure 2

Visual Analog Scale



The resting heart rate was collected from each participant in order to measure the target heart rate during exercise. The target heart rate should be within zone 1 which is 60% to 70% of the maximum heart rate that represents the optimal heart rate during the physical activities according to American college of sport medicine ACSM (see Table 2) and it was monitored through ***heart rate monitor*** (Monark, Swedan). ***Gym’s mats*** and ***emergency belt*** was used for participants at Human Performance Lab and Wellness center. ***Gym’s mate*** was available and surrounding the treadmill from each side that’s aim to protect the participant from any possible falling risk.

Table 2
Target Heart Rate calculation.

Target Heart Rate	[(percentage) X (220 – participant age)]
	• The percentage should represent Zone1 (60% to 70%). • 220 represent the estimated maximum heart rate by American Heart association.

Procedures

The data collection occurred at the Human Performance Lab at Barry University. All the students were able to see the posted flyers at Barry University about their participation in this study. After the random selection, they were informed of the aim of the study and they were given a questionnaire form about the participants' age, height, weight, and their medical conditions. This personal information were entered anonymously in Sway balance website to create a special file for each student. Additionally, they signed the consent form provided by the investigator and the investigator signed as well. They were reminded to wear sport shoes and suitable clothing for running. Later, the participants were assigned into 3 different groups: Control group (no running) , 20 minutes running group, and 30 minutes running group, and All the participants received the same and exact Sway balance testing.

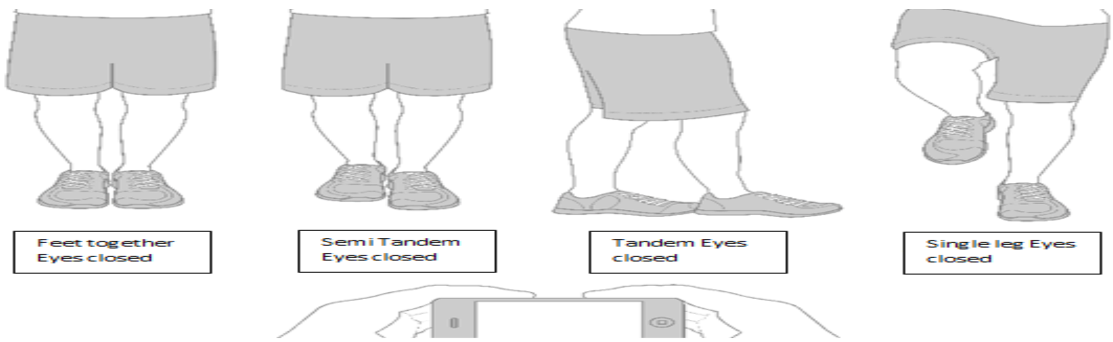
Balance protocol

The entire protocol for each participant was approximately 40 to 50 minutes and each protocol was composed of the following: Step 1 Sway balance tests (A) as a baseline, Running procedures on the treadmill, Step 2 Sway balance tests (B) immediately after the running procedure on the treadmill, Step 3 Sway balance tests (C) after 5 minutes from the running on the treadmill, and Step 4 Sway tests (D) after 10 minutes from the running on the treadmill.

The Sway balance test were repeated four times: one before the running procedure and three after. The Sway balance tests included four tasks: 1) Feet together with closed eyes, 2) Semi tandem with closed eyes, 3) Tandem with closed eyes, and 4) Single leg supported with closed eyes. The detailed instructions in those tests were visually provided by Sway balance application as pictures and the participants were able to follow the exact steps. Those tests needed to be addressed in specific time without any distraction from the surrounding environment. (See Figure 3)

Figure 3

Sway balance application Protocol.



Running protocol

Each participant were able to run on the treadmill for 5 minutes with speed of 3.5 Mph to warm up faster and to get ready for the experiment. Then, the participants were running according to their group classification as 20 minutes of running, or 30 minutes of running or no running at all (control group). The running speed started with self-selected speed (Mph) during the running procedure, the participants were asked frequently by the instructor to indicate their level of exertion by using RPE Borg scale and to monitor their personal target heart rate.

Heart rate equation was used for each individual [220 – age = Heart rate]. Then, the result multiplied by 60% and 70% to indicate the low end and high end zones. The participant's heart rate was monitored between 60%- 70% of their maximum heart rate by increase or decrease the speed accordingly. The HR was monitored through the chest strap monitor and Borg scale. The running procedure must be stopped immediately if the participant is not able to continue the running task, or if he/she reached the number 20 on the Borg scales, or exceeded the heart rate, or upon his/her request, noticeable change in heart rhythm .

To clarify the running procedure, the participants were warming up until they reach 60% of their maximum heart rate based on HR strap monitor. Then they started their self-selected speed running. If their heart rate goes beyond 70%, then the treadmill speed will be decreased or if their heart rate less than 60%, the treadmill speed will be increased. Since there are individual differences between participants, the investigator reminded each participant to monitor heart rate and to insure that the HR is between 60% to 70%.

Data Analysis

Statistical analysis were performed using Statistical Package for Social Sciences Software (SPSS) (SPSS Inc, Chicago IL). The Sway balance scores (for feet together test, tandem test, Semi-tandem test, and single leg support test) were available in Sway balance website for each participant profile and it can be accessed only by using Sway ID and password that provided by the company of Sway balance application. Statistical analysis were performed according to the following methods.

The main hypothesis in this study is to determine the effect of exercise duration and recovery on balance on Sway balance scores. This hypothesis was tested through a Frideman test with the independent variable of exercise durations with pre sway test and post sway tests with 3 levels (immediately after running procedure, after 5 minutes, after 10 minutes) and the dependent variables of Sway balance test scores (Feet together, Tandem, Semi-tandem, and Single leg support). Due to violation of the assumption of normality, Friedman test were used which is alternative to one-way ANOVA with repeated measures. It was used to identify the differences between and within group because the date distribution.

These varied Sway balance scores were determine if there is any difference in balance at several point post exercise that resulted from running on treadmill. The level of significance in this study was 0.05. The average of the collected data was used and it is confidentially stored .

Results

The purpose of the current study was to investigate the effect of exercise (running) duration on balance by using Sway balance application. The goal of the study was to assess the applicability of Sway Balance Mobile Application (Sway Medical) that is introduced to determine the effect of exercise on balance. The results of the Sway balance mean that higher scores indicated better balance and lower scores indicated poor balance and the participants were not stable enough and they might be at risk of falling (see the following Tables 3,4,5 and 6 for the full results). The method is considered effective due to its applicability outside the laboratory and the easiness in transporting it from one region to another.

Since there were a large number of difference between male and female subjects, repeated measure ANOVAwas required to study the effect of gender on Sway positions and the effect of gender on running durations. However, there was no significant differences or interactions between gender regarding to Feet together position (FT), Semi-Tandem position (ST), Tandem position (T), and Single leg position (SL). Also, there was no significant difference regarding gender and durations.

Table 3

The means and standard deviations (SD) of Feet Together positions for all groups.

	FT Pre	FT Immediately	FT Post 5 min	FT Post 10 min
Control Group	98.78 SD = .84	98.5510 SD = .95	98.3680 SD = 1.9	97.6490 SD = 2.65
20 min Group	96.1411 SD = 3.25	97.2722 SD = 2.7	99.0267 SD = .87	98.3689 SD = 1.22
30 min Group	95.4590 SD = 5.82	98.8180 SD = 1.33	96.7490 SD = 4.30	99.0920 SD =.97

- FT = Feet Together

Table 4

The means and standard deviations (SD) of Semi-Tandem positions for all groups.

	ST Pre	ST Immediately	**ST Post 5 min**	ST Post 10 min
Control Group	96.7170 SD = 2.97	95.54 SD = 4.48	**98.79** **SD = .82**	97.88 SD = 1.36
20 min Group	96.9722	95.97	**97.45**	97.00

	SD = 3.03	SD = 3.70	**SD = 1.51**	SD = 2.17
30 min Group	98.1240 SD = 2.30	94.61 SD = 7.55	**99.28** **SD = .43**	98.51 SD = 1.51

- ST = Semi-Tandem

Table 5

The means and Standard deviations (SD) of Tandem positions for all the groups.

	T Pre	T Immediately	T Post 5 min	T Post 10 min
Control Group	93.29 SD = 5.48	92.60 SD = 6.11	87.31 SD = 27.75	93.30 SD = 7.05
20 min Group	85.48 SD = 11.22	79.94 SD =15.39	80.29 SD = 28.11	90.98 SD =7.29
30 min Group	91.5610 SD = 8.88	92.69 SD = 6.33	93.51 SD = 6.41	96.59 SD = 2.23

- T = Tandem

Table 6

The means and Standard deviations (SD) of Single Leg positions for all the groups.

	SL Pre	SL Immediately	SL Post 5 min	SL Post 10 min
Control Group	74.82 SD = 14.93	58.90 SD = 34.15	58.94 SD = 39.72	86.00 SD = 6.78
20 min Group	69.47 SD = 15.66	45.14 SD = 31.83	82.46 SD = 12.53	67.58 SD = 28.89
30 min Group	82.72 SD = 9.42	65.22 SD= 42.60	84.27 SD = 12.13	63.80 SD = 42.63

- SL = Single leg.

- ***Within Subjects differences (for the sway balance positions).***

Four individual and different Friedman tests were performed for each stance. The Friedman tests shown that there were no significant difference regarding some positions: Feet together (FT), Tandem (T), and Single leg (SL). However, there was a significant difference in the balance scores in the Semi-Tandem position (ST). Especially, Semi-tandem after 5 minutes from the running procedure in all the three groups. $\chi2(2) = 8.567$, $p = 0.014$. Also, there was significant differences between control group and 20 minutes group and between control 20 minutes group and 30 minute group in Semi-tandem after 5 minutes from exercise.

- ***between Subjects differences was used to compare the results between the three groups (Control, 20 minutes, and 30 minutes)***

For both Control group and 30 minute group, Friedman Test shown no statistically significant difference between groups in the following positions Feet together (FT), Tandem (T), Semi-Tandem (ST), and Single leg (SL).

For 20 minute group, Friedman Test shown statistically significant difference within groups in the following positions; Feet together (FT), Tandem (T), Semi-Tandem (ST), and Single leg (SL). $\chi2(14) = 64.635, p = 0.000.$ So, it was required to perform another Friedman test (follow up) for each position to see if there any differences between the 20 minute group. There were no statistically significant in the 20 group regarding Feet together (FT), Tandem (T), and Semi-Tandem (ST). However, there is significant difference with Single leg position (SL) $\chi2(3) = 10.733, p = 0.013$. Another follow up for Single leg position at the 20 minutes shown that (single leg immediately –

single leg after 5 minutes) were significantly different when it compared to the others single leg durations.

Discussion

The various sections of this research have emphasized on the analysis of the effect of exercise durations that followed exercise on balance. Balance is considered to experience changes when different levels of exercise durations are experienced by a person. To achieve the stated objectives, the research was aimed to meet the following objectives in the research process. 1.To determine why the Sway balance application is preferred for this research. 2. To evaluate the effects of exercise durations on balance and recovery that tested by the Sway balance application?

Majority of people with balance issues fail to acquire treatment due to high cost associated with the process using other measurement methods. By introducing the treadmill and the Sway balance application, this may experience an attractive intervention measure due to low cost associated with the Sway application. It is considered that Sway application is easier to implement in the healthcare sector or other departments (Patterson, et al., 2011). During data collection, participants expressed their interest to use Sway Medical application anytime and anywhere, the convenience and easy to use tool. However, those subjects were not familiar with the automatic given instructions and Also, if the subjects misunderstand the visual instruction from Sway balance application, they will not be able to repeat the balance test again because they data will be affected or it will affect the other results. That’s why, the researcher must confirm to the subjects that they have to perform the Sway balance tests on specific time without any possible delay. If the subject completely did not follow the exact visual instructions from the Sway Balance application, the running procedures and Sway balance measurement should be repeated in different timing.

At the lower leg, exercising diminishes the feeling of position and the control of balance (Rohleder, 2012). For instance, it is noted that plantar flexor and dorsiflexor exhaustion instigated through an isokinetic convention influenced the control of balance. Rohleder (2012) reported a noteworthy increase in medial-lateral(M-L) body influence motions sufficiency contrasted and a no exhausted state. Both Semi-Tandem (ST) and Single Leg (SL) positions are classified as Mediolateral position (ML) since they sway the human body side to side. On the other hand, this current study shown that both Semi-Tandem and Single leg support were affected more than other positions.

Marchant, Greig and Scott (2009) have reported that fatiguing the plantar-flexors and the dorsi-flexors muscles trigger a huge increase in the mediolateral (M-L) body influence motions contrasted to non-fatigue state. This demonstrates that fatigue has serious consequences for the body systems as it influences the critical aspects of balance. Even though running on treadmill fatigues the overal body, it can also effect specific muscle groups in the lower limb and can be considered as “any exercise-induced reduction in the capacity to generate force or power output” Chaubert & Paillard (2012). Salavati et al. (2007) found that combined invertor and evertor fatigue created significantly larger increases in the M-L direction compared to combined plantar flexor and dorsiflexor fatigue.

Our findings shown that there was a clinically decrease in the overall balance scores for the exercise groups specially with Semi-Tandem (ST) and Single Leg (SL) positions when it was compared to the control group (no exercise group). There was no clinical or statistical differences between Feet together (FT) and Tandem (T) which can be explained that (FT) is more stable and has greater base of support while (T) was easy to performed by subjects. Also, the center of mass (COM) was within base of support (BOS).

Moreover, there was a significant difference in the balance scores with the Exercise group (20 minute)_ Single leg position (SL)_ when it was compared to both control group and Exercise group (30 minute). This can be explained that 20 minutes of running classified as short exercise which is much beneficial for the entire body. Short duration of running has a constructive effect on human body and it needs more time for recovery compared to long running duration. However, after long duration of running would expose the human body to fatigue or exhaustion after and can stimulate adaptations that enable to resist fatigue better the next time. That explained why it was not affected with the 30 minutes group of running when it was compared to 20 minutes group of running (Fitzgerald, 2016).

Also, for the Semi-Tandem position (ST), it was significantly different only after 5 minutes from the running procedure for all the three groups. The possible reasons behind this interpretation is that both (ST) and (SL) had a narrow base of support and it was not possible to maintain more upright and steady position during static balance activities. Another possible reason is that the subjects were not familiar to the new positions. Especially with (ST), it seemed that it was less natural and acquired position for participants and it needs more practice.

Semi-tandem is to keep one foot behind the other so that the big toe of one foot is close to the other side of the heel. This position is acquired and considered as less natural for normal people.

From another aspect, balance is a complex sensorimotor process that requires the consolidation of data from the multiple sensory systems to generate appropriate motor responses to maintain an upright position and prevent falling (Lohse & Sherwood, 2011). Many factors have been played a major role to control the balance. These factors may be physiological (e.g., inability to maintain power output; (Wolfson, Judge, Whipple & King 1995), cognitive (Gosselin, Rassoulian & Brown, 2004) and emotional or psychological (Miller & Bird, 1976). The effects of the previous factors can be more clear when performing complicated tasks (i.e., Single leg support) or when performing in challenging environments.

Until now there is no clear explanation why Semi- Tandem position is affected by the running protocol especially after 5 minutes. However, it makes sense that both Semi- Tandem and Single leg were affected because of many biomechanical reasons. Both of those two position characterized by very narrow Base of support It is normal that the participants feel less stable than when the feet are spread apart. Another biomechanical factor that the subjects had to support themselves in the single leg position, they needed to shift their weight side to side because their bodies trying to find the new Center of Gravity .Swaying itself considered as Postural strategy and it usually performed automatically by the human body to restore balance if the sway is occurring outside the stability limits.

It is not recommended to performing those two positions after heavy exercising for non-athlete populations because they will be at high risk of injury and falling.

Limitations

This project suggested that subjects gave their best performance during their 30 or 20 minutes of running. However, this type of running does not reflect the actual performance of the outdoor runners population. The data should be collected under different conditions including weather exchange, type of surface, type of shoes, gender, and specific age group. In addition, emotional factors were not controlled for.

Another limitation was the time to recruit subjects. It was so hard to collect subjects during Summer and it cannot be control because of lack of students number during this specific period of the year.

Conclusion

There were no significant differences shown between exercise groups _ 20 and 30 minutes _ and control group regarding Feet Together (FT) and Tandem (T) balance scores. This is probably because both Feet Together (FT) position have a wide base of support (BOS) and this lead to increase the stability. Also, Tandem (T) position sounds to be familiar for most of subject and it was easy to be performed. On the other hand, there were a noticeable and significant difference with Semi tandem after 5 minutes (SL5) from the exercise. Also, there was a significant difference with Single Leg (SL) with Exercise group (20 minutes of running) when it was compared to the control group and Exercise group (30 minutes of running). The other positions were not significantly different but it is important to know that there was a difference from a clinical setting which mean diagnostic and therapeutic aspects. Further studies will be needed to investigate if there any possible difference exist with a non-athlete population or using different durations.

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Appendix

Appendix A : Recruitment Flyer

You are invited to participate in our study.

It is about EFFECT OF TREADMILL EXERCISE DURATIONS ON BALANCE ABILITY MEASURED BY SWAY BALANCE APPLICATION.

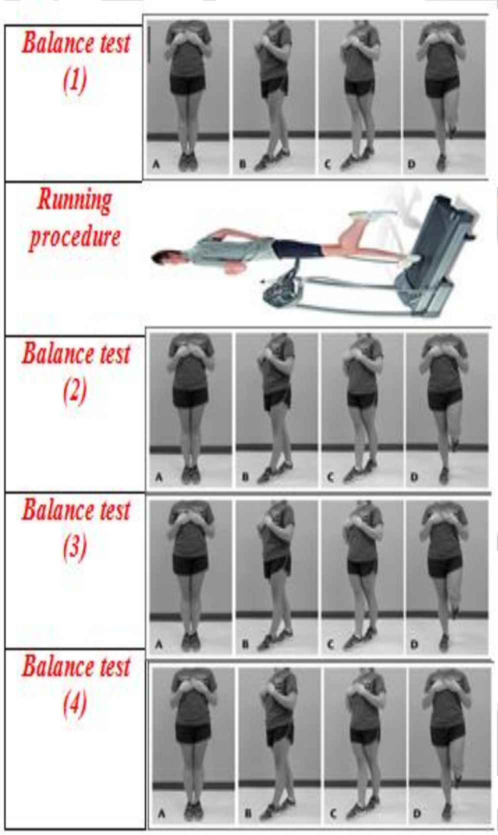
If you decide to participate in this research, you will be assigned to an exercise group or a control group. Your balance will be measured after the running procedures by using Smart phone application in four different positions and it will be repeated for 3 times (see the picture).

Inclusion Criteria:-

Please consider participating in this study If you are Barry University students age 18 years or older.

If you are physically active individual running at least three times a week for at least 30 minutes.

If you are able to run for at least 30 minutes on 60 to 70% of your Maximum heart rate.



Exclusion Criteria:-

You need to be free at least for one year from any sign of dizziness, vestibular or visual problems, lack of coordination due to neurological diseases such as Ataxia or Parkinson diseases, lower limb injuries, and limb length discrepancy larger than 2 cm that will be evaluated by tape measurement and no pain measured by visual analogue scale. You should not have suffered from any cardiovascular disease, high blood pressure, or pain in the chest. Also, you should not take any medication for these conditions. However, if you have any of these

We highly appreciate your time and effort. For further information or participation, don't hesitate to contact us:

Mohammad Zougar:
Mohammad.zougar@mymail.barry.edu, at (412) 251-4563
Dr.Claire Egret:
cegret@barry.edu, at (305) 899-3064
Ms. Barbara Cook:
bcook@barry.edu, at (305) 899-3020

Appendix B
Barry University
Informed Consent Form

Your participation in a research project is requested. The title of the study is the effect of treadmill exercise durations on balance ability measured by sway balance application. The research is being conducted by Mohammad Zougar, a graduate student in the School of Human Performance and Leisure Science at Barry University, and is seeking information that will be very useful in the field of movement science and sport injuries. The aim of the research is to study the effect of running durations on the body balance by using Sway balance application. We anticipate the number of participants to be maximum 40.

If you decide to participate in this research, you should be free at least for one year from any sign of dizziness, vestibular or visual problems, lack of coordination due to neurological diseases such as Ataxia or Parkinson diseases, lower limb injuries, and limb length discrepancy larger than 2 cm that will be evaluated by tape measurement and no pain measured by visual analogue scale. Also, you should not have suffered from any cardiovascular disease, high blood pressure, or pain in the chest and or taking any medication for these conditions. However, if you have any of these signs you cannot participate in this study.

You will be assigned to an exercise group or a control group. You will be asked to perform a 5 minutes of walking on a treadmill to warm up. Then, you will perform the First sway balance measurements with eyes closed (feet together, tandem, semi-tandem, single leg), by using Sway balance application. After this you will be asked to run on the treadmill for 20 or 30 minutes at 60-70 of your max heart rate, depends on your group assignment. You will be requested to do Balance testing for three more times; the Second Sway balance test will immediately after the running protocol, the Third Sway balance test will be after 5 minutes from the running protocol, the Fourth Sway balance test will be after 10 minutes from the running protocol. The total duration of experiment will be within 45 to 55 minutes. No videotape or any type of recording will be involved in the research.

Your consent to be a research participant is strictly voluntary and should you decline to participate or should you choose to drop out at any time during the study and you will have no adverse effect. You can change the participating day if you cannot make it. There will be no adverse effects and consequences. The risks of involvement in this study are minimal, and are not different than the risk you have when you are running, and include mild fatigue or muscle soreness or falling from treadmill. This will be minimized by a warm up exercise before the running protocol, by using gym mats around the treadmill, and emergency clip belt to stop the treadmill in case of emergency. In case of an injury, the investigator will call 911 and/or the athletic trainers on site. Although there are no direct benefits to you, your participation in this study may help our and your understanding of the effect of exercise durations on balance and how to avoid possible risk of injury.

As a research participant, information you provide will be held in confidence to the extent permitted by law. Any published results of the research will refer to group averages only and no names will be used in the study. Data will be kept in a locked file and password locked computer in the researcher's office. Your signed consent and questionnaire forms will be kept separate from the data and from each other. All questionnaire forms of subjects that were not qualified for the study will be shredded. All data will be maintained for a minimum of 5 years upon completion of the study. All data will be destroyed after 5 years.

If you have any questions or concerns regarding the study or your participation in the study, you may contact me Mohammad Zougar at (412) 251-4563, Mohammad.zougar@mymail.barry.edu or my supervisor Dr. Claire Egret at (305) 899-3064, cegret@barry.edu or the Institutional Review Board point of contact, Barbara Cook, at (305) 899-3020, bcook@barry.edu If you are satisfied with the information provided and are willing to participate in this research, please signify your consent by signing this consent form.

Voluntary Consent

I acknowledge that I have been informed of the nature and purposes of this experiment by Mohammad Zougar and that I have read and understand the information presented above, and that I have received a copy of this form for my records. I give my voluntary consent to participate in this experiment.

______________________ __________

Signature of Participant *Date*

______________________ __________

Researcher *Data*

Appendix C

Barry University

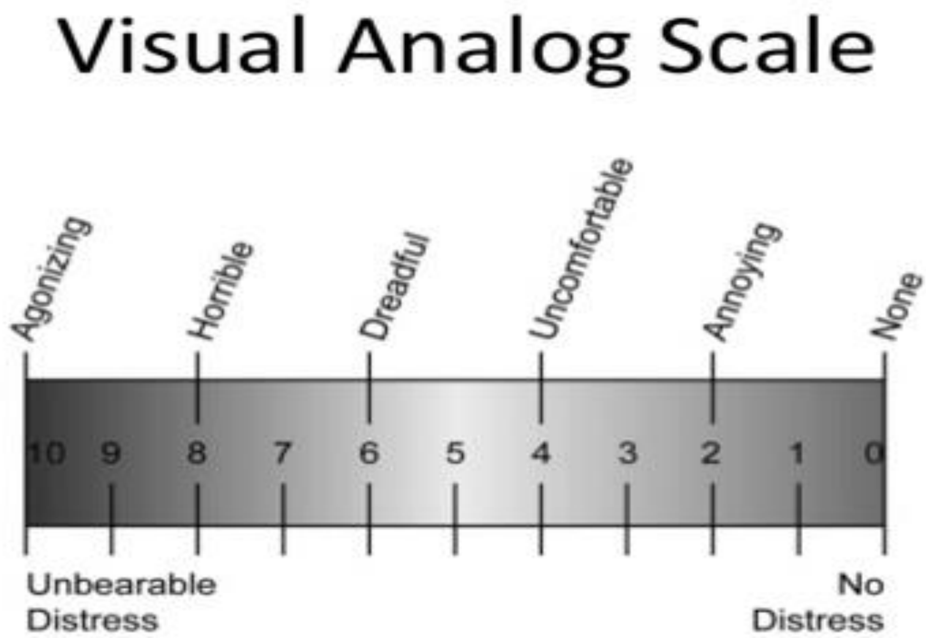
Physical activity readiness questionnaire PAR-Q

Participant number or coding: …………………………………………………..
Age : ……………….Sex: ……………………..
Weight: ……………Height: …………………..

1- Has your doctor ever said that you have a heart condition and that you should only perform physical activity recommended by a doctor?
Yes […..] No […..]
2- Do you feel pain in your chest when you perform physical activity?
Yes [….] No [….]
3- In the past month, have you had chest pain when you were not performing any physical activity?
Yes [……..] No [………..]
4- Do you lose your balance because of dizziness or do you ever lose consciousness?
Yes [……..] No [………..]
5- Do you have a bone or joint problem that could be made worse by a change in your physical activity?
Yes [……..] No [………..]
6- Is your doctor currently prescribing any medication for your blood pressure or for a heart condition?
Yes [……..] No [………..]
7- Do you know of any other reason why you should not engage in physical activity?
Yes [……..] No [………..]
8- Do you have pain in lower limb during walking or running?
Yes [……..] No [………..]
9- Do you have any medical conditions in your vision?
Yes [……..] No [………..]
10- Do you have currently any neurological diseases which can affect your coordination?
Yes [……..] No [………..]

11 Do you have leg length discrepancy? (you will be measured by the investigator)?
Yes [……..] No [………..]

12 Do you suffer from any pain. Can you indicate your level of pain by using the following Visual Analog Scale?
Yes [……..] No [………..]



I give my voluntary consent to fill and use the questionnaire and I have been informed by Mohammad Zougar that these data will be destroyed immediately after finishing the study.

Participant Signature:______________________________
Date:__________________
Investigator Signature:______________________________
Date:__________________