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Balance Comparison of Open- and Closed-Back Shoes

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BALANCE COMPARISON OF OPEN- AND CLOSED-BACK SHOES

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Submitted to the Graduate Faculty of the
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for the degree of
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This Scholarly Project, submitted by Tiffany J. Hemberger, Sara J. Henderson and Eric A. Loiland, in partial fulfillment of the requirements for the Degree of Doctor of Physical Therapy from the University of North Dakota, has been read by the Advisor and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Graduate School Advisor)

(Chairperson, Physical Therapy)
PERMISSION

Title Balance Comparison of Open- and Closed-Back Shoes

Department Physical Therapy

Degree Doctor of Physical Therapy

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Signatures

Tiffany Hemberger
Sara Henderson
Eric Koehl

Date 12-15-05
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ABSTRACT

A growing number of healthcare professionals have been choosing to wear an open-back shoe rather than a traditional closed-back shoe in the workplace. Healthcare professionals incorporate dynamic balance and quick reactions during direct patient interaction. The purpose of the study was to determine if dynamic balance would be affected in healthcare professionals when wearing open-back shoes versus closed-back shoes.

Thirty-two healthcare professionals or students of healthcare professions (28 females and 4 males) were recruited for this study. Subjects ranged in age from 20 to 62 years (mean age 28.2 years), with the majority being physical therapists or physical therapy students. Subjects were required to use their own shoes during testing to ensure familiarity.

A shoe questionnaire was given to each participant prior to testing. The majority of participants felt their open-back shoes provided adequate support and did not affect their balance while walking. However, when given options to select activities that may be limited while wearing open-back shoes, the following were most commonly selected: walking speed, step length and transfers.

Three tests were conducted in both open- and closed-back shoes to assess whether dynamic balance was affected between the two types of footwear. The tests included the Forward Lunge Test (FLT) using the NeuroCom® Balance Master (NBM®), Functional
Reach Test (FRT), and Single Leg Hop (SLH)—Forward and Backward. Type of footwear and testing order were randomly selected by each individual. Three trials were conducted for each test and an average was calculated.

Results indicated a better test performance in the closed-back shoes. A significant difference in dynamic balance was found between the open- and closed-back shoes in the following areas: FLT—Distance (right, p = .022; left, p = .048 respectively), FRT (p = .005), and SLH—Forward and Backward (p = .000, p = .001 respectively). The results of this study indicate that dynamic balance may be affected by open-back shoes worn by a healthcare professional.

This is significant to healthcare professionals who are responsible for the safety of their patients. Although there is little evidence in literature about the safety of open-back shoes, the results of this study indicates that patient and professionals’ safety may be compromised with open-back shoes. Further research is needed to determine if there should be specific policies and procedures regarding open-back footwear worn in healthcare facilities to ensure maximal safety for the patient and the healthcare employee.
CHAPTER I
INTRODUCTION/LITERATURE REVIEW

In recent years, a growing number of healthcare workers have been choosing to wear an open-back shoe rather than the traditional closed-back shoe in the workplace. Healthcare is a profession with a high number of occupational injuries, many of which could be prevented. According to the Occupational Safety and Health Administration (OSHA), over one third of all major occupational injuries occurred as a result of slips or trips.¹ Many healthcare workers perform skills that require static and dynamic balance. In addition, quick reactions are necessary in order to protect patients in the case of unexpected falls or accidents. A possible consequence is that healthcare workers who wear open-back shoes will have slower reaction times, therefore predisposing themselves and their patients to a greater risk of injury. Many healthcare facilities have dress codes that regulate the type of footwear that employees can wear. However, these policies usually only refer to wearing closed-toed, low-sole height, slip-resistant and rubber sole material footwear. Because open-back shoes are fairly new to the market, research has not been established regarding the safety of these shoes or how they may affect healthcare workers and their patients.

An overall understanding of balance is important and knowledge of factors that can alter or change a person’s balance. According to Nashner,² balance is a very complex process that incorporates sensory detection of the body’s motions,
sensorimotor information from within the body’s central nervous system, and the execution of appropriate musculoskeletal responses. Beyond the intrinsic components of balance, which can often be affected by disease processes, many extrinsic conditions can also greatly affect someone’s balance. These extrinsic conditions can include the environment, such as slippery floors and cluttered spaces, as well as footwear. Footwear can affect balance through the collar height, sole height, slip resistance, and the stability of the foot in the shoe.

OSHA has set certain regulations regarding environment influences of falls in the workplace. Keeping floors clean, dry, and free from clutter is required by the administration in order to ensure the safety of workers and clients. OSHA’s standards state that all healthcare professionals wear a “safe” shoe. However, it does not define what type of shoe is safe. Research investigating the effect of shoe collar height, sole hardness, and heel height on balance is reviewed below. However, little evidence exists regarding safety of open-back shoes.

A study conducted by Lord et al., looked at shoe collar height and sole hardness and the affect on balance in older women. Forty-two women ages 60-92 years underwent both static and dynamic balance assessments. Static balance was assessed through body sway measured using a swaymeter. Dynamic balance was assessed using the swaymeter, a maximal balance range test, and a coordinated stability task. This study determined that high-collared footwear offers better support for balance than a low-collared shoe.

Lord and Bashford tested balance in elderly women while wearing different types of footwear. The footwear tested included a standard low-heeled shoe, a high-heeled shoe, and the subjects own shoes all compared with barefoot. Thirty women, ages
60-89 years, were tested by looking at body sway, maximal balance range and a coordinated stability task. The results indicated that the subjects tested best in barefoot and in low-heeled shoes when compared to high-heeled or their own shoes. This study indicated the importance of proper heel height and it's affect on balance.

Arnadottir and Mercer's study on elderly individuals tested balance and gait with bare feet, walking shoes, and dress shoes. Thirty-five women were tested between the ages of 65 and 93 years. Performance on the Functional Reach Test was decreased in dress shoes when compared to barefoot and walking shoes. This was seen on both linoleum and carpeted floors. Timed Get Up and Go Test was best when performed on linoleum in walking shoes and worst in dress shoes. The 10-Meter Walk Test was performed best by participants when on carpeted floor and again while wearing walking shoes. These results indicate the importance of footwear on performance of balance and gait assessments.

Koepsell et al's study determined the risk of falls in elderly individuals when wearing various types of footwear. Risk of falls was assessed in 1,371 adults over the age of 65. It was discovered that non-athletic shoes, such as oxfords or loafers, had a 1.3 times higher occurrence of falls than athletic shoes. Barefoot had a higher risk of falls than both the athletic and non-athletic footwear. The study concluded the risk of falls in older adults is related to choice of footwear. Whereas, Robbins et al's study evaluated balance in older men in shoes with different types of soles, and it was discovered that hard, thin soled shoes offered the best stability for older men. An additional study done by Robbins evaluated the materials which were used in the soles of shoes. Subjects included 30 older men (mean age of 66 years) and 30 younger men
(mean age of 34 years). Sole resilience was assessed during locomotion of the subjects. It was found that soles with low resiliency offer better stability than a material with a high resiliency. Shoes with high resiliency are often chosen because of their comfort and ability to disperse plantar pressure, but these factors may be jeopardizing stability in the wearer due to the destabilizing effect of the soft sole.8

OSHA stresses the important role that footwear may play in preventing slips or trip.2 This is of greater significance in occupational settings in which floors may be wet or slippery, such as hospitals or clinics. Staal et al9 conducted a study on slips and falls in healthcare workers as related to footwear. The study examined methods used to reduce slips by other occupations, such as commercial fishing and restaurant industry. These fields relied heavily on footwear for occupational safety. This study incorporated the use of positive grip shoes for healthcare workers and measured the amount of slips and falls resulting from the use of these shoes. Staal hypothesized that positive grip shoes would decrease slips and falls by 50% and were able to prove their hypothesis through this study. This study indicated that footwear can have a dramatic effect on the number of slips and falls of healthcare workers and other occupations and industries.

Current research makes it clear that an individual’s balance can be affected by numerous factors, footwear being just one of them. Research exists regarding the effects of shoe collar height, sole resiliency, and sole grip on a person’s balance. Little to no research is specific to an open-back shoe. This research is important to obtain because of the new found popularity of these types of shoes, especially in healthcare workers.
Balance can be defined as static or dynamic. Static balance is when the center of gravity remains within and individuals base of support. Dynamic balance is when the center of gravity extends beyond an individuals base of support. Liston et al. looked at the test-retest reliability of the Balance Master when testing stroke patients. Twenty subjects with hemiparesis were assessed using dynamic tests as well as static standing to assess their postural sway. These results were evaluated for concurrent validity by using the Berg Balance Scale and the gait velocity as a criterion standard. This study concluded that the Balance Master was effective in testing dynamic balance, but not static balance. This led the researcher to conclude that dynamic balance is a better predictor of functional balance and performance.

Dynamic balance can be assessed using a number of different tests. Some commonly used dynamic balance assessments include the Forward Lunge Test (FLT), the Functional Reach Test (FRT) and the Single Leg Hop—Forward and Backward (SLH).

Forward Lunge Test

The FLT is a functional assessment of dynamic balance that can be performed on the NeuroCom® Balance Master (NBM®). The NBM® is a measurement device used to establish quantitative assessment of static and dynamic balance. Subjects perform a lunge in a forward plane of motion while the NBM® records and analyses data collected. Rose et al. conducted research regarding the reliability of several functional mobility tests including the Sit-to-Stand, Walk, Tandem Walk, Step Up/Over and the Forward Lunge Test. The researchers compiled a database of 176 subjects between the ages of 20 and 80 years, and their performance of these tests on two separate days. Retest reliability was found to be excellent, excluding the Walk Test, for these assessments.
Functional Reach Test

The FRT is commonly used to assess dynamic balance and risk of falls by assessing the distance a subject can reach with a stable base of support. A study conducted by Duncan et al\textsuperscript{12} established the FRT as a measure of stability and determined its precision and reliability. A total of 128 volunteers between the ages of 21 and 87 years were assessed. The study found that FRT will determine margin of stability, detect balance impairments, and detect decreased in balance over time. Weiner et al\textsuperscript{13} assessed 28 inpatient male veterans (ages 40-105 years) undergoing rehabilitation and 13 control subjects. The study determined that the FRT can be used to determine improvements in balance over time.

Duncan et al\textsuperscript{14} conducted a study to determine the validity of the FRT in predicting the risk of recurrent falls. A total of 217 elderly veterans, ages 70-104 years underwent a prescreening in order to determine a baseline. They were then monitored for falls for 6 months. Prior to beginning their research, it had been established that the FRT had criterion and concurrent construct validity as well as reliability. After research was finalized, researchers found that the FRT does in fact offer predictive validity for identifying risks of recurrent falls, specifically for elderly male veterans.

A study done by Hageman et al\textsuperscript{15} looked at the effect of age and gender on aspects of balance using the Balance Master system. Two groups were tested in this study. Twenty-four subjects ages 20-35 years represented the younger group and twenty-four subjects ages 60-75 years represented the older group. Subjects completed the Limits of Stability Test and the FRT. Gender had no effect on the outcomes of balance, yet age did have an influence on the results. An inverse relationship in age versus balance was
determined. This can be confirmed with previously noted literature that as age increases, there is an increase in balance deficits.

Normative data for the FRT has been established for all age groups. As reported in Bennett and Karnes, age related changes are as follows: 20-40 years old = 16.73 inches for men, 14.64 inches for women; 41-69 years old = 14.98 inches for men, 13.81 inches for women; 70-87 years old = 13.16 inches for men, 10.47 inches for women.

Single Leg Hop

The SLH determines dynamic balance ability by assessing a maximal distance hop on one leg. Ageberg et al tested the reliability of repeated measures in SLH. Seventy-five healthy participants (36 men and 39 women) ages 15 to 44 years (mean age = 29.5 years) performed the hop forward and land 3 consecutive times and an average was taken. SLH—Forward was found to have a high reliability (p = .96) in test—retest of the subjects. With the results in mind, it is likely that a single tester should be able to obtain reliable results from testing a single subject multiple times under different conditions.

Ross et al found that test—retest reliability for SLH was high (p > .90). Eighteen, healthy male cadets were assessed (age = 20.2 ± 1.2 years). Subjects were asked to hop forward as far as they could and the distance was measured.

Purpose

The purpose of the study was to determine if deficits in balance would exist in healthcare workers who chose to wear open-back shoes in the workplace. It is becoming increasingly popular for healthcare workers to wear these types of shoes for reasons of comfort and convenience. This study looks at whether an open-back shoe offers balance
and stability as sufficient as closed-back shoes. The results can be applied to healthcare workers, to help provide the best possible patient care and to minimize risk to the patient and themselves. Also, results may be applicable to the patient when choosing footwear most appropriate for their level of function.

After reviewing the literature, the following question was posed. Is the balance of healthcare workers, when assessed by the FLT, the FRT and the SLH—Forward and Backward, compromised by wearing an open-back shoe when working with patients? The hypothesis states that balance will be compromised in healthcare workers wearing an open-backed shoe. The null hypothesis states that there will be no difference in individuals’ balance between types of footwear.

Clinical Application

In today’s healthcare system patient safety is a primary goal. Balance among the healthcare workers is an important and controllable component of maintaining the safety of patients. In a situation where unexpected events can lead to injuries of the patient, it is important for the healthcare worker to be able to react and adapt quickly to compensate for these actions. Footwear is an easily modifiable change which could possibly affect, or improve, the healthcare workers ability to react to unforeseen circumstances. This may benefit healthcare workers by reducing the number of occupational injuries and the patient by ensuring their safety.
CHAPTER II

METHODOLOGY

Prior to the start of this study a project proposal was submitted to the University of North Dakota Institutional Review Board (Appendix A) for approval and for the use of human subjects for this study (IRB# 200505-370). This proposal included a consent form (Appendix B), a health questionnaire and a footwear questionnaire (Appendix C). The health questionnaire was designed to eliminate at risk individuals and to establish baseline information regarding overall health status and past medical history prior to testing. The footwear questionnaire provided subjective information about the individuals' open-back shoes including length of time owned, size, and stability offered.

Participants

Physical therapy and other health care students, as well as local health care professionals, were recruited by word of mouth for study participation. Subjects were given a consent form prior to testing. Participation in this study was voluntary. Subjects were asked to participate if they met the following criteria: at least 18 years of age, no past medical history or taking any medications that may affect their balance, no history of unexplained falls, no chronic joint instability in the lower extremities, and no use of an assistive device for mobility. Shoe requirements included that the 2 types of shoes have sole height no greater than one inch, and have been owned for a minimum of one week.
The open-back shoes could have a minimal lip on the back (Figures 2-4, Appendix D). Thirty-two subjects met these criteria and participated in the study.

Instrumentation

The following dynamic balance tests were chosen to assess individuals balance in the two types of footwear: Forward Lunge Test (FLT) on the NeuroCom® Balance Master (NBM®), Functional Reach Test (FRT) and Single Leg Hop (SLH)—Forward and Backward. These dynamic balance tests all are simple to apply and have been found to be reliable assessments of dynamic balance. Static balance was not assessed as it research has found it not to be a good predictor of functional performance.10

Forward Lunge Test

The FLT is a reliable measure of dynamic balance and reaction time and is performed on the NBM. The NBM®, Version 7.06 (NeuroCom® International, Inc, 9570 SE Lawnfield Road, Clackamas, OR 97015-9611). It is a machine that consists of two computerized 9”x 60” force plates with pressure sensors at each of the four corners. These sensors collect data and send it to the computer program to be stored and analyzed (Figure 1).

Lunging requires strength, adequate range of motion, balance, coordination and control in order to be successfully completed.20 Components measured with FLT are distance, contact time, impact index and force impulse.

Distance defines the length of the forward step relative to the participants’ body height. Contact time is the total time in seconds (sec) the lunging foot is in contact with the forceplate before beginning its return to the start position. A low contact score reflects a short contact time or a faster movement. A prolonged contact time can result if
the individual had sensory deficit, poor balance or incoordination. Impact index is the force applied through the lunging leg and is reported as a percentage of total body weight (% BW). A low impact index score reflects a good eccentric control. If the subject feels unstable and does not fully weight-shift onto the forward lunging leg a low impact score may result, but may not necessarily indicate good eccentric control. Force impulse, reported in percent of body weight per second (% BW/sec), is the total work done by the lunging leg during its eccentric and concentric contractions. A high force impulse score and a low contact time indicate efficient use of biomechanics and can be interpreted as a large amount of work performed in a short amount of time. The reverse is also true; a
low force impulse score and a high contact time indicates a poor work performance in a longer amount of time.

**Functional Reach Test**

The FRT is commonly used among researchers to assess dynamic balance and risk of falls due to the high reliability. It is assessed by measuring maximal distance a subject can reach while maintaining a fixed base of support. Equipment included a taped start line and a measuring unit for recording distance. The difference between a measurement taken with an extended arm to 90° and the maximum distance reached without taking a step is considered the functional reach. Three testing trials are averaged to report results.

**Single Leg Hop—Forward and Backward**

The SLH is also a reliable measure of dynamic balance, which was used to measure the distance an individual can safely hop. A single leg hop test requires strength, coordination and balance to complete. Subjects hopped forward and backward as instructed. Equipment included a taped start line and a secured measuring tape to measure the distance hopped.

**Assessment Procedures**

Subjects were seen at UND-PT Research Lab. Two researchers were present at all testing sessions. One researcher gave instructions for the test to be performed and another one stood as a spotter for subject safety. Each subject was informed of the purpose of the study and he or she was required to sign a consent form and complete a health questionnaire and a footwear questionnaire. Upon arrival, each subject was asked to randomly select a number out of a container. The number was assigned to the
questionnaires, consent form and data. Subjects selecting even numbers were assigned closed-back shoes for the first testing procedures. Subjects selecting odd numbers were assigned open-back shoes for the first testing procedures. The NBM® was calibrated prior to each individual testing session. Subject information obtained from the health questionnaire was entered onto NBM® (date of birth, height, subject number and type of shoe). Subjects were instructed to select their testing order by blindly placing the three tests in a random order. The FLT was performed on the NBM® platform while the FRT and SLH—Forward and Backward were performed and measured on tile flooring.

**Forward Lunge Test**

Subjects were told to stand at the end of the force plates so that both of his/her feet are entirely on the plates. The subjects were shown a video demonstration on the NBM® computer of how to perform the lunge and then asked if they had any questions. They were then instructed that the computer screen would first show “Hold Steady” and then show “Go.” Following this cue, the subjects were instructed to lunge as far forward and as quickly as possible, and return to their starting position. A practice trial was given to ensure understanding of the instructions. Upon completion of practice trial, testing trials were conducted. Subjects repeated the test 3 times with each leg.

**Functional Reach Test**

Subjects were asked to stand with their feet behind the line on the floor with the right side of their body towards the wall. A yardstick was secured to the wall parallel to the floor and at the subjects shoulder level. They were instructed to extend their right arm with fingers extended while an initial measurement was taken from their 3rd distal phalanx. Subjects were then asked to reach as far forward as they could without falling,
taking a step or leaning against the wall. Each participant was given a practice trial before three testing trials were conducted.

**Single Leg Hop Test**

Each subject was instructed to place their feet entirely behind the line. A measuring tape was permanently placed on the floor at the end of the starting line and extended 10 feet parallel to the testing area. The results were measured from the start line to the point at which their heel landed with the forward test and where their toe landed with the backward test. They were then asked to hop with one leg as far as they comfortably could, landing on the same leg. Demonstration was performed by the examiner prior to testing. Subjects were instructed to take a practice hop with each leg to determine which leg was to be used during testing. A minimum of one spotter was present during testing to ensure subject safety. Once the subject chose a testing leg, another practice hop was performed, followed by three testing trials were completed.

**Pilot Study**

Researcher training was done through instrumentation sessions prior to beginning a pilot study. These sessions included an orientation to the equipment as well as numerous case study assignments designed to teach the navigation through the computer program as well as understanding analysis of results.

A pilot study was conducted prior to research testing in order to establish intrarater (test-retest) reliability of the testers. Ten subjects ranging in age from 21-28 years were assessed using the FLT on the NBM®, FRT, and the SLH—Forward and Backward. The assessment procedure used was the same as described above. Participants were instructed to wear comfortable shoes (no open-back shoes allowed),
which may have been a casual work shoe or a tennis shoe. To establish intrarater reliability, the same procedure was followed a second time and each participant was required to repeat the testing procedures approximately one to two days later. The SPSS Version 10.0 (SPSS, Inc., Chicago, IL) was used to calculate intrarater reliability for all tests.

**Intrarater Reliability**

An intraclass correlation coefficient (ICC) was calculated for each test using repeated measures of analysis of variance (ANOVA). This was done in order to assess test-retest reliability for the FLT, FRT and SLH—Forward and Backward (Table 1). A general ICC measurement of .75 or greater is considered to be reliable, however to have a high reliability reading the ICC would be .90 or greater. All of these tests, with the exception of contact time, reported an ICC greater than .75 indicating reliability. The FRT and SLH—Forward and Backward indicate the highest ICC values, indicating a higher reliability rate (.9631 and .9803 respectively).

**Table 1. Test-Retest Reliability For the Administered Tests**

<table>
<thead>
<tr>
<th>Test</th>
<th>Component</th>
<th>ICC</th>
<th>r</th>
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<tbody>
<tr>
<td>Forward Lunge Test</td>
<td>Distance: (% body height)</td>
<td>L .7853</td>
<td>.6518</td>
</tr>
<tr>
<td></td>
<td>R .8569</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Impact Index: (% body weight)</td>
<td>L .7589</td>
<td>.6149</td>
</tr>
<tr>
<td></td>
<td>R .9109</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Contact Time: (seconds)</td>
<td>L .6790</td>
<td>.5262</td>
</tr>
<tr>
<td></td>
<td>R .7225</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Force Impulse: (% body weight/sec)</td>
<td>L .7689</td>
<td>.6476</td>
</tr>
<tr>
<td></td>
<td>R .7556</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Functional Reach Test</td>
<td>Distance Reached: (inches)</td>
<td>.9631</td>
<td>.9341</td>
</tr>
<tr>
<td>Single Leg Hop</td>
<td>Distance: Forward (inches)</td>
<td>.9416</td>
<td>.8898</td>
</tr>
<tr>
<td></td>
<td>Backward</td>
<td>.9803</td>
<td>.9614</td>
</tr>
</tbody>
</table>
Data Analysis

All data were stored from the three trials, but data analysis included trials two and three only. Trial one was removed during data analysis to eliminate subject learning curve making the results more consistent. Data gathered from the FLT, FRT and SLH—Forward and Backward were entered into the SPSS version 10.0 software program. From there, descriptive statistics including mean and standard deviation were calculated. A paired t-test was performed and the results were recorded.

Recording of Results

Upon completing this study, the results were analyzed and recorded. A copy was given to the University of North Dakota Library of Health Sciences, as well as the Department of Physical Therapy.
CHAPTER III

RESULTS

The purpose of this study was to determine if there was a significant difference on individuals in balance when wearing open- and closed-back shoes. The data were analyzed using descriptive and analytical statistics. The results were calculated using the Forward Lunge Test (FLT), Functional Reach Test (FRT) and Single Leg Hop (SLH)—Forward and Backward.

Subject Profile

Thirty-two subjects ages 20-62 years (mean age = 28.19 years, SD = 10.88 years) participated in this study. There were 28 females and 4 males, the majority of whom were physical therapists and physical therapy students. One participant completed the FLT and the FRT but choose not to perform the SLH tests. All subjects participated in randomly selected tests, which included the FLT, FRT, and SLH—Forward and Backward. Each test was performed using open-back shoes and closed-back shoes.

Questionnaire Results

A shoe information questionnaire was given to each participant prior to testing. Participants were asked to answer “Yes” or “No” to questions regarding support and balance while wearing open-back shoes (Table 2). The majority of participants felt that their open-back shoes provided adequate support and did not affect their balance while walking. Additionally, subjects were asked to select various activities in which they felt
were limited or changed when wearing open-back shoes. The options available were the following: walking speed, step length, frequent stopping, transfers, gait training, exercise demonstrations, or other. Walking speed, step length and transfers were the most commonly selected activities (Table 3).

Table 2. Responses Obtained From Shoe Questionnaire

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you feel open-back shoes provide adequate support?</td>
<td>23</td>
<td>9</td>
</tr>
<tr>
<td>Do you feel your balance is affected in any way while you wear open-back shoes?</td>
<td>7</td>
<td>25</td>
</tr>
</tbody>
</table>

Table 3. Activities Subjects Felt Are Affected When Wearing Open-Back Shoes

<table>
<thead>
<tr>
<th>Activity</th>
<th>Percent Reported (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking Speed</td>
<td>45.2</td>
</tr>
<tr>
<td>Step Length</td>
<td>45.2</td>
</tr>
<tr>
<td>Frequent Stopping</td>
<td>19.4</td>
</tr>
<tr>
<td>Transfers</td>
<td>32.3</td>
</tr>
<tr>
<td>Gait Training</td>
<td>9.7</td>
</tr>
<tr>
<td>Exercise Demo’s to patients</td>
<td>22.6</td>
</tr>
<tr>
<td>Other</td>
<td>10.0</td>
</tr>
</tbody>
</table>

Descriptive Statistics

Descriptive statistics include mean and standard deviation. Seven of the 8 variables measured were normally distributed, thus paired t-tests were used for analyzing differences between conditions of open- or closed-back shoes. The 8th variable, SLH—
Backward distance demonstrated kurtosis with the closed-back condition. However, parametric and non-parametric analysis demonstrated a significant difference in distance between conditions, paired $t$-test results were chosen to be reported for this variable as well (Table 4).

Analytical Statistics

Analytical statistics were used to determine if a significant difference existed between tests when comparing open-back to closed-back shoes. The statistics included $t$-statistic, degrees of freedom and significance. The data was assessed using a parametric paired sample $t$ test. An alpha level of .05 (95% confidence interval) was used to determine the level of significance.

A significant difference was found in FLT, FRT, SLH—Forward and Backward (Table 4) between open- and closed-back shoes. The remaining FLT components (impact index, contact time, and force impulse) failed to show a significant difference between open- and closed-back shoes.
Table 4. Open-Back versus Closed-Back Test Descriptives of Paired t-Test

<table>
<thead>
<tr>
<th>Test</th>
<th>Component</th>
<th>n</th>
<th>Open-back</th>
<th>Closed-back</th>
<th>t</th>
<th>df</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward Lunge Test</td>
<td>Distance: (% body height)</td>
<td></td>
<td>L</td>
<td>31 48.42 (7.04)</td>
<td>50.31 (6.80)</td>
<td>2.42</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>R</td>
<td>31 49.15 (7.08)</td>
<td>50.31 (7.19)</td>
<td>2.07</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Impact Index: (% body weight)</td>
<td></td>
<td>L</td>
<td>31 28.11 (13.45)</td>
<td>28.45 (14.15)</td>
<td>0.28</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>R</td>
<td>31 28.85 (10.69)</td>
<td>28.90 (12.90)</td>
<td>0.04</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Contact Time: (seconds)</td>
<td></td>
<td>L</td>
<td>31 0.98 (0.26)</td>
<td>1.00 (0.27)</td>
<td>0.80</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>R</td>
<td>31 1.01 (0.26)</td>
<td>1.03 (0.30)</td>
<td>0.90</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Force Impulse: (% body weight/sec)</td>
<td></td>
<td>L</td>
<td>31 105.58 (23.25)</td>
<td>107.32 (24.18)</td>
<td>0.82</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>R</td>
<td>31 109.29 (23.77)</td>
<td>110.94 (26.86)</td>
<td>0.85</td>
<td>30</td>
</tr>
<tr>
<td>Functional Reach Test</td>
<td>Distance reached (inches)</td>
<td></td>
<td>31 14.09 (2.53)</td>
<td>14.68 (2.59)</td>
<td>3.02</td>
<td>30</td>
<td>.005*</td>
</tr>
<tr>
<td>Single Leg Hop</td>
<td>Distance: Forward (inches)</td>
<td></td>
<td>30 47.72 (14.83)</td>
<td>51.27 (16.05)</td>
<td>5.16</td>
<td>29</td>
<td>.000*</td>
</tr>
<tr>
<td></td>
<td>Backward (inches)</td>
<td></td>
<td>30 22.90 (8.48)</td>
<td>24.99 (9.47)</td>
<td>3.77</td>
<td>29</td>
<td>.001*</td>
</tr>
</tbody>
</table>

* Significant at α ≤ .05 level of significance
CHAPTER IV
DISCUSSION

The results of this study show, when comparing open-back shoes to closed-back shoes, a significant difference \( (p \leq .05) \) is present in the following categories: Forward Lunge Test (FLT)—Distance, Functional Reach Test (FRT), Single Leg Hop (SLH)—Forward and Backward. The test results indicate that healthcare professionals and students perform dynamic balance activities better when wearing closed-back shoes. These findings agree with the hypothesis, which stated that balance would be compromised in healthcare workers wearing an open-back shoe. The 3 other components of the FLT (contact time, force impulse and impact index), assessed with the NMB\textsuperscript{®} did not show significant difference between the two types of shoes.

The participants performed statistically better during the FLT—Distance, the FRT, and SLH—Forward and Backward while wearing closed-back shoes. Participants wearing their closed-back shoes were able to forward lunge a mean difference of 1.53 inches further then in their open-back shoes. The mean difference for the FRT was 0.59 inches further in closed-back shoes. The mean difference for SLH—Forward was 3.55 inches and SLH—Backward was 2.09 inches further in the closed-back than in the open-back shoes. This shows a statistical significance but may have questionable clinical relevance. These tests simulate the types of dynamic movements made by healthcare professionals throughout the workday. The rationale for these tests is that if a patient is
losing their balance the healthcare professional may need to perform reactive movements 
(such as a reach, lunge, or hop) to catch the patient from a fall which could lead to further 
complications. The findings indicate that closed-back shoes provided individuals with 
more stability during these tests. In healthcare, patient safety is the primary goal. These 
results show that wearing an open-back shoe may offer less support and therefore, may 
influence patient safety during handling by the healthcare worker.

The findings of this study were similar to the subjective impressions reported by 
the participants. A substantial number of participants reported during testing that they 
felt less stable when performing the FLT, FRT and SLH in their open-back shoes. The 
most common subjective report throughout testing trials was that participants had to curl 
their toes to keep the shoes from coming off. Most participants reported they did not feel 
they had done as well, when the tests were performed in open-back shoes.

When asked if activities were limited while wearing open-back shoes the 
participants reported the following activities were mostly affected: walking speed, step 
length, patient transfers and exercise demonstrations to patients. This was consistent with 
the results of the study.

Limitations/Recommendations

Although this study showed a significant difference in dynamic balance when 
comparing open-back to closed-back shoes, it is acknowledged that there were certain 
limitations present. First, participants were not required to have one specific type or 
design of shoes, which may have caused the results to be less accurate. Some of the 
open-back shoes worn during testing fit snug and stayed on the subject’s feet well. Other 
shoes were loose fitting and at times subjects had difficulty keeping them on. This was
most evident in the backward SLH test where subjects had the tendency to jump out of their shoes. Most subjects reported they needed to curl their toes to keep their open-back shoe from coming off during testing. Beyond the stability in the shoes, many other footwear variables can affect the balance of the individual, including heel height, collar height, sole resiliency, and grip. It is recommended that the future studies standardize types of shoes being tested. By standardizing the shoe brand, variation in shoe fit and structure could be eliminated. These variations may have unintentionally affected the results of this study.

Secondly, variability in the newness of shoes and the frequency worn may have had an affect on results. This could have potentially skewed the results to reflect that there was a less dramatic difference between the two footwear types.

Thirdly, it was intended that all subjects would be tested in a closed environment free from all outside distractions, but this was not always available due to scheduling conflicts. Unfortunately, due to the limited space available for testing and scheduling conflicts some outside distractions occasionally occurred.

Fourthly, the ages tested did not accurately represent the working healthcare population. The mean age tested was 28.2 years of age, which may be younger than the average healthcare worker. In future studies it would be recommended that the population being tested would come primarily from the healthcare community rather than students. Future research may also benefit from using a more diverse age range and a larger sample size. Balance has been shown to be inversely related to age. Older professionals may not be able to perform as well as a younger population due to
decreased flexibility and strength as well as possible health complications that inevitably occur with age. These limits in physical conditioning may skew the results.

Finally, in the pilot study test-retest reliability was found for all components of the FLT, FRT, and SLH. However, reliability of the components of the FLT was compared to an ICC of 0.75 (good) rather than an ICC of 0.90 (high), which was used for the additional tests. The FLT may not have been significant in 3 of the 4 components due to the test-retest reliability rather than the affect the shoes had on lunge performance.

It is also recommended that further research may benefit from the use of other tests. Since the necessity of a direct forward lunge is highly unlikely, a multi-directional lunge may better assess the impact on balance in an open-back shoe. By incorporating a multi-directional lunge test into further research, a better representation of real-life situations can be evaluated. This may affect the significance of impact index, contact time, and force impulse components of the FLT. Another test that may benefit future research is the Quick Step and Turn Test on the NMB®. This would ensure that the tests have functional relevance to the healthcare setting. Asking the participant to actually perform a transfer, for example, would greatly improve the correlation between the study results and real-life situations in a clinical setting.

Conclusion

Dynamic balance tests performed in the research study were affected by the type of footwear worn by the participant. Participants performed consistently better with closed-back versus open-back shoes with the dynamic testing. This data gathered and evaluated in this study may be applied to healthcare professional when making recommendations to their patients or colleagues regarding proper footwear. This
becomes increasingly important for individuals with previously existing balance deficits or those responsible for patient safety. Further research is needed to better understand the affects of wearing an open-back shoe in the work place and to determine if there should be policies regarding open-back footwear worn in healthcare facilities to ensure maximal safety for the patient and the healthcare employee.
APPENDIX A
REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW
University of North Dakota Institutional Review Board

Date: 5/11/2005
Project Number: IRB-200505-370

Principal Investigator: Henderson, Sara; Hemberger, Tiffany; Loiland, Eric; Danks, Meridee

Department: Physical Therapy

Project Title: Balance Comparison of Open and Closed Back Shoes

The above referenced project was reviewed by a designated member for the University's Institutional Review Board on May 12, 2005 and the following action was taken:

☑ Project approved. Expedited Review Category No.

Next scheduled review must be before: May 11, 2006

☑ Copies of the attached consent form with the IRB approval stamp dated May 12, 2005 must be used in obtaining consent for this study.

☑ Project approved. Exempt Review Category No.

☐ This approval is valid until as long as approved procedures are followed. No periodic review scheduled unless so stated in the Remarks Section.

☐ Copies of the attached consent form with the IRB approval stamp dated must be used in obtaining consent for this study.

Minor modifications required. The required corrections/additions must be submitted to RDC for review and approval. This study may NOT be started UNTIL final IRB approval has been received.
(See Remarks Section for further information.)

☐ Project approval deferred. This study may not be started until final IRB approval has been received.
(See Remarks Section for further information.)

REMARKS: Any unanticipated problem or adverse occurrence in the course of the research project must be reported within 72 hours to the IRB Chairperson or RDC by submitting an Unanticipated Problem/Adverse Event Form.

Any changes in protocol or Consent Forms must receive IRB approval prior to being implemented. You must submit a Protocol Change Form with all revised research documents to include changes to protocol, consent forms, or supportive materials, with the appropriate signatures, to Research Development and Compliance for review and approval.

PLEASE NOTE: Requested revisions for student proposals MUST include adviser's signature. All revisions MUST be highlighted.

☑ Education Requirements Completed. (Project cannot be started until IRB education requirements are met.)

cc: Tom Mohr; Meridee Danks; Dean School of Medicine

Signature of Designated IRB Member
UND's Institutional Review Board

5-12-5

If the proposed project (clinical medical) is to be part of a research activity funded by a Federal Agency, a special assurance statement or a completed 310 Form may be required. Contact RDC to obtain the required documents.

(Revised 07/2004)
May 13, 2005

Sara Henderson; Tiffany Hemberger; Eric Loiland; Meridee Danks
2513 Knight Dr., Apt. 4
Grand Forks, ND 58201

Dear Ms. Henderson, Ms. Hemberger, Mr. Loiland, and Ms. Danks:

We are pleased to inform you that your project entitled “Balance Comparison of Open and Closed Back Shoes” (IRB-200505-370) has been reviewed and approved by the University of North Dakota Institutional Review Board (IRB). The expiration date of this approval is May 11, 2006. If it continues beyond this date without an approved Research Project Review and Progress Report, the project approval will be terminated and you will have to resubmit your full proposal.

Research investigators are responsible for obtaining informed consent and for ensuring that no human subject will be involved in the research prior to obtaining the consent. Only copies of the IRB approved consent form stamped with the approval and expiration dates may be used. Each person signing the written consent form must be given a copy of the form.

As principal investigator for a study involving human participants, you assume certain responsibilities to the University of North Dakota and the UND IRB. Specifically, any adverse events or departures from the protocol that occur must be reported to the IRB immediately. It is your obligation to inform the IRB in writing if you would like to change aspects of your approved project, prior to implementing such changes.

All Full Board and Expedited proposals must be reviewed at least once a year. Approximately ten months from your initial review date, you will receive a letter stating that approval of your project is about to expire. This notice will give you detailed instructions for submitting a Research Project Review and Progress Report to the IRB. In order to avoid a discontinuation of IRB approval and possible suspension of your research, this form must be returned to the Research Development and Compliance (RD&C) office at least six weeks before the expiration date listed above. If your research, including data analysis, is completed before the expiration date, you must submit a Research Project Termination form to RD&C so your file can be closed. The required forms are available on the IRB website.

If you have any questions or concerns, please feel free to call me at (701) 777-4279 or e-mail at patriciapeterson@mail.und.nodak.edu.

Sincerely,

Patricia Peterson
IRB Administrative Secretary

Enclosures
Consent Form

Balance Comparison of Open and Closed Back Shoes

You are invited to participate in a research study investigating the correlation between open back shoes and balance. This study is conducted by physical therapy students (Tiffany Hemberger, Eric Loiland and Sara Henderson) in the graduate program attending the University of North Dakota in collaboration with advisor Meridee Danks.

The purpose of this study is to determine if wearing open back shoes affects balance. You will be asked to participate in a one time testing session that will take 20-45 minutes to complete. Your participation will include multiple balance assessments using a piece of equipment called the Balance Master. This is commonly used in PT departments to assess balance. Balance will also be assessed with a backward walking drill, standing functional reach test and a one-legged hopping test.

The risks from this study are minimal and may include loss of balance. To maximize participant’s safety a safety belt will be used and a spotter will be present during all testing procedures. Also to increase the participant’s safety

The results obtained from this study will remain confidential. All data collected will be identified by randomly assigned numbers with matching numbers on each consent form. All data and consent forms will be kept in separate and confidential locked files within the Physical Therapy department. These files will remain locked at all times and only the researchers, the advisor and people who audit IRB procedures will have access to the data. After a period of three years all documents will be destroyed.

This study is entirely voluntary. If at any time you wish to withdraw for any reason, you may do so. Your decision to decline or withdraw from participation will not affect your relationship with the University of North Dakota in any way.

Investigators hold the right to exclude any participants if they do not meet the minimum requirements of the study or we feel their health status may be at risk. If in the event an injury shall occur as a result of this research project, the investigators along with the University of North Dakota will not be held responsible in any way.

All investigators are available to answer any questions prior to, during or after the completion of this study. You may contact any of the following investigators: Tiffany Hemberger (218) 773-2884 or themberger@medicine.nodak.edu; Eric Loiland (701) 739-3901 or eloiland@medicine.nodak.edu; Sara Henderson (701) 610-6108 or shenderson@medicine.nodak.edu, or advisor Meridee Danks at (701) 777-3861. If you have any other questions or concerns, please call Research Development and Compliance Department at the University of North Dakota at (701) 777-4279. All participants will be provided a copy of this consent form.

I have read all of the above and I willingly agree to participate in this study. It was explained to me by Tiffany Hemberger, Eric Loiland and/or Sara Henderson.

Participant’s Signature

Date
Health Questionnaire

(Questions 1 and 2 are necessary information for use for the balance master)

1. What is your age?

2. What is your height?

3. What is your occupation/field of study?

4. Are you involved or will you be involved in direct patient care?

5. Have you had any recent injuries to your lower extremity joints (i.e. ankle/knee sprains or strains)

6. Do you have any past medical history that may affect your balance? (i.e. inner ear infection, dizziness, lightheadedness) problems? If so, please explain.
   ____Yes ____No

7. Are you currently taking any over the counter or prescribed medications that affect your balance? If so, please list all.
   ____Yes ____No
Shoe Information

• What is your shoe size?

• Do you wear foot orthotics in these shoes or any shoes? If so, please note for what condition.
  ____Yes   ____No

• How long have you had the shoes you have been asked to use today?

• How many days per week (on average) do you wear these shoes?

• Do you feel they provide adequate support?
  ____Yes   ____No

• Do you feel your balance is affected in any way while you wear them?
  ____Yes   ____No

• Please check any activities that are limited or changed when wearing these shoes.
  o Walking Speed
  o Step Length
  o Frequent Stopping
  o Transfers
  o Gait Training
  o Exercise Demo’s
  o Other__________

• What is your reason for wearing these type shoes
  o Comfort
  o Fashion
  o Price
  o Convenience
  o Orthopedic
  o Fit
  o Other__________

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Figure 2. Example 1 of open-back shoes.

Figure 3. Example 2 of open-back shoes.
Figure 4. Example 3 of open-back shoes.
APPENDIX E
**Forward Lunge Test**

"Stand with both feet entirely on the end of the forceplates."

"Place your hands at your hips (may place them down at your sides)"

"You will be performing a forward lunge. Please watch the computer screen for a demonstration."

"You will get one practice trial before the testing begins and then you will have three testing trials."

"When the test begins, you will see the words **HOLD STEADY** appear on the screen."

"When you see the word **GO,** lunge forward with your Left/Right leg as far and as fast as you can and return to the start position and remain standing."

"We will repeat this 3 times with each leg."
Name: 5closedback, 5
ID: ATID00349
Date of Birth: 
Height: 5'11"
Comments:

Diagnosis: Not Specified
Operator: Not Specified
Referral Source: Not Specified

File: FD349.DRX
Date: 7/22/2005
Time: 12:02:03

Forward Lunge

Vertical Force
%Body Wt

%Body Ht
% Difference

Distance
%Body Ht
% Difference

Impact Index
%Body Wt
% Difference

Contact Time
sec
% Difference

Force Impulse
%Body Wt-sec
% Difference

Data Range Note:
User Data Range: 20–39

Post Test Comment:

APPENDIX F
Functional Reach Test

"On this test, we will be measuring how far you are able to reach while keeping your balance."

"Please stand with the right side of your body against the wall and your feet behind the taped line."

"You will get one practice trial before the testing begins and then you will have three testing trials."

"Raise your arm so it is parallel with the yard stick."

"Keeping your arm straight out in front of you, reach forward as far as you can without losing your balance, taking a step or leaning against the wall."
APPENDIX G
Single Leg Hop—Forward

“You will be performing a single leg hop.”

“Please stand with your feet behind the taped line.”

“Choose one leg to hop with—you will use this same leg for each trial.”

(“If you have already done the Single Leg Hop—Backward, please use the same leg.”)

“You will have one practice hop before three testing trials.”

“When you are ready, hop as far as you can.”

Single Leg Hop—Backward

“You will be performing a single leg hop, backwards.”

“Please stand with your heels behind the taped line.”

“Choose one leg to hop with—you will use this same leg for each trial.”

(“If you have already done the forward single leg hop, please use the same leg.”)

“You will have one practice hop before three testing trials.”

“When you are ready, hop as far as you can.”
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