2006

Orthotic devices in the treatment of limb length discrepancies

Jenni R. Jespersen
San Jose State University

ORTHOTIC DEVICES IN THE TREATMENT OF LIMB LENGTH DISCREPANCIES

A Thesis

Presented to

The Faculty of the Department of Kinesiology

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

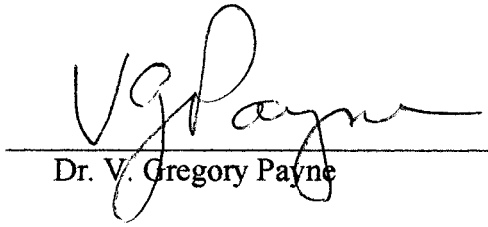
Master of Arts

by

Jenni R. Jespersen

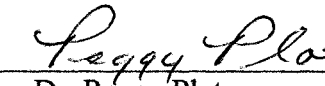
May 2006

APPROVED FOR THE DEPARTMENT OF KINESIOLOGY



Dr. V. Gregory Payne

Dr. Leamor Kahanov



Dr. Peggy Plato

APPROVED FOR THE UNIVERSITY

ABSTRACT

ORTHOTIC DEVICES IN THE TREATMENT OF LIMB LENGTH DISCREPANCIES

by Jenni R. Jespersen

Limb length discrepancies are common and can lead to several problems in the lower extremity. They are usually treated with a heel lift inserted in the shoe of the short limb. While successful in correcting the discrepancy, heel lifts do not address underlying issues that may be the cause of the discrepancy. Orthotic devices have been suggested as an alternative treatment method, but current research demonstrating their efficacy in treating limb length discrepancies is lacking. Abnormal foot biomechanics are a common cause of limb length discrepancies, and research demonstrates the efficacy of orthotic devices in correcting these abnormal biomechanics. By correcting abnormal biomechanics, orthotic devices were hypothesized to correct resulting limb length discrepancies. Nineteen individuals participated in this study and were measured for limb length discrepancies with and without orthotic devices. Results indicated that orthotic devices were successful in treating limb length discrepancies.

ACKNOWLEDGEMENTS

The author wishes to express her gratitude and appreciation to all who contributed in any way to the completion of this thesis. Special thanks are extended to Dr. David R. Francis for his contributions, help, and advice throughout this project; to Jessica Meyer and Lani Criddle for their help in completing the research; and to the author's family and friends for their continued love, support, and encouragement.

Table of Contents

Chapter I – Introduction	1
Statement of the Problem	5
Purpose of the Study	5
Research Hypotheses	5
Delimitations	6
Limitations	6
Definitions	7
Operational Definitions	8
Summary	9
Chapter II – Review of Literature	10
Magnitude of Limb Length Discrepancies	10
Methods of Measurement and Detection of Limb Length Diescrepancies	11
Methods of Nonsurgical Treatment for Limb Length Discrepancies	14
Function and Purpose of Orthotic Devices	16
Summary	17
Chapter III – Methods	19
Pilot Study	19
Participants	20
Instrumentation	21
Research Design	22
Analysis of Data	24

Summary 25

Chapter IV – Results 26

Statistical Results 27

Summary 30

Chapter V – Discussion and Conclusions 31

Discussion 32

Conclusions 35

Suggestions for Future Research 36

References 37

Appendix A – Approval from the San Jose State University Human Subjects-Institutional Review Board 40

Appendix B – Participant Consent Form 42

Appendix C – Participant Questionnaire 44

Appendix D – Limb Length Discrepancy Measurement Sheet 46

Appendix E – Pilot Study Data 48

Appendix F – Raw Data 50

List of Tables

Table 1	Summary of LLD Changes	27
Table 2	Two-way ANOVA (gender, age)	28
Table 3	Summary of Measurements of LLDs	29
Table 4	ANOVA Results for LLD Measurements	29

List of Figures

Figure 1	Research Instrumentation	21
Figure 2	Iliac Crest Palpation to Detect a LLD	22
Figure 3	Iliac Crest Palpation with Book Correction	23

Chapter I

Introduction

Limb length discrepancies (LLD) exist in a high proportion of today's population (Brady, Dean, Skinner, & Gross, 2003; Hanada, Kirby, Mitchell, & Swuste, 2001; Schuit, Adrian, & Pidcoe, 1989). If severe enough, LLDs can lead to problems throughout the lower limb. Mild LLDs are present in 90-95% of the population (Brady et al., 2003; Subotnick, 1981), and severe LLDs may exist in 4-8% of the population (Brady et al., 2003). Two types of discrepancies exist: anatomical and functional. Anatomical discrepancies involve a difference in the length of the osseous components of the lower limbs. Functional discrepancies are inequalities in the length of the lower limbs due to improper foot mechanics, shortening of soft tissues, joint contractures, ligamentous instability, and/or skeletal malalignments (Brady et al., 2003). Anatomical and functional discrepancies may be present independently or simultaneously. Discrepancies occur in varying degrees of severity, from mild discrepancies of only a few millimeters to severe discrepancies of over several centimeters. Required corrections or treatment are determined by the type and severity of the discrepancy.

While individuals with mild LLDs may be asymptomatic, many problems can be present within the lower extremity, as well as other parts of the body, that are associated with significant LLDs (Bhave, Paley & Herzenberg, 1999; Brady et al., 2003; Schuit et al., 1989). Because of the differences in the length of the two legs, discrepancies change the alignment and biomechanics of the lower extremity. A body will compensate for the length differences to correct the imbalance. The compensatory mechanisms may lead to

pain in the knee, hip, and/or low back (Schuit et al., 1989). Low back pain and scoliosis may be associated with LLDs (Beattie, Isaacson, Riddle & Rothstein, 1990; Hoyle, Latour & Bohannon, 1991). Brady et al. (2003) indicate that LLDs can lead to scoliosis and excessive abnormal foot pronation. Subotnick (1981) associates LLDs with pain in the low back, pelvis, or hip, which may include sciatica, as well as low back strains. Because of the problems that may result from significant discrepancies and their effects on lower extremity biomechanics and alignment, it is important to correct or reduce them whenever possible.

Patients with mild LLDs who are asymptomatic may not require treatment; however, patients with significant discrepancies usually require treatment and correction to resolve the discrepancy and its resultant problems. Severe anatomical LLDs require surgical procedures to lengthen or shorten the bone(s) of the lower extremity (Brady et al., 2003). For less severe discrepancies, noninvasive techniques, such as the use of a heel lift or orthotic device, are more appropriate (Bandy & Sinning, 1986; Brady et al., 2003; Schuit et al., 1989; Subotnick, 1981). The efficacy of orthotic devices in correcting or reducing LLDs will be investigated.

Most studies investigating the treatment methods of mild to moderate LLDs use a heel lift to correct or reduce the discrepancy (Bandy & Sinning, 1986; Brady et al., 2003; Schuit et al., 1989). Subotnick (1981) suggests incorporating a forefoot lift into the heel lift treatment. Heel lifts are used to level the pelvis by adding height to the shorter limb (Schuit et al., 1989). The results of studies on heel lift intervention depict varying degrees of efficacy and success to correct discrepancies. Agreement among researchers

exists that intervention strategies should be determined by the individual circumstances of each LLD, such as the type of discrepancy, the patient's symptoms, and the patient's response to different treatment methods (Bandy & Sinning, 1986; Brady et al., 2003).

Little research has been conducted on the use of orthotic devices alone to correct or reduce LLDs. Bandy and Sinning (1986), Brady et al. (2003), and Subotnick (1981) all suggest orthotic devices may be an appropriate treatment method for discrepancies, but a lack of research has been conducted to evaluate efficacy. The purpose of an orthotic device is to correct abnormal biomechanics of the foot (Heiderscheit, Hamill, & Tiberio, 2001). Improper biomechanics of the foot can lead to a number of problems in the lower extremity, including a LLD (Brady et al., 2003; Kilmartin & Wallace, 1994; Marks, 2004). Orthotic devices are typically prescribed to correct excessive pronation of the foot (Kilmartin & Wallace, 1994), the most common abnormality. Three types of orthotic devices exist: soft flexible, semi-flexible or semi-rigid, and rigid functional orthotics. Rigid functional orthotic devices are constructed from a mold taken of the patient's feet. This allows the devices to be customized to each patient's needs and circumstances, and they provide the most effective support and the best correction of improper biomechanics (Doxey, 1983; Jordan, 1939; Subotnick, 1975).

The concept of using an orthotic device to correct or reduce a LLD is attractive because it allows for the correction of the biomechanical abnormalities, such as abnormal or excessive foot pronation or pelvic malrotation that may exist with the LLD (Subotnick, 1981). Heel lifts simply change the height of the limb, but do not address biomechanical factors that may be contributing to the discrepancy (Bandy & Sinning, 1986). Schuit et

al. (1989) state that heel lifts alone may not adequately allow proper foot function to occur in conjunction with the LLD correction. In addition, Subotnick (1981) states that unnecessary heel lifts may result in unilateral weaknesses. Orthotic devices provide a method to treat other problems of the lower extremity that may result from abnormal biomechanics of the foot together with treating LLDs (Kilmartin & Wallace, 1994).

The ability of orthotic devices to relieve painful symptoms of the low back, hip, knee, ankle, and foot is undisputed based on patient satisfaction and clinical results. However, little scientific evidence exists that indicates their efficacy in limiting abnormal motion of the foot (Heidersheit et al., 2001; Kilmartin & Wallace, 1994; Marks, 2004). Because of this lack of scientific evidence, health insurance companies frequently do not reimburse for orthotic devices (Segedy & Edwards, 2003). Without research that illustrates the clinical efficacy of orthotic devices, insurance companies do not recognize the necessity and do not reimburse for these rehabilitative devices. Many practitioners are hesitant to prescribe orthotic devices when insurance companies will not reimburse (Segedy & Edwards, 2003), and patients are often unwilling to pay the high cost of a custom made orthotic device. Further research on the efficacy of orthotic devices is necessary to provide insurance companies with evidence that will support reimbursement (Segedy & Edwards, 2003).

The potential benefits of using orthotic devices over heel lifts and other methods to correct or reduce LLDs warrant further research in this area. The implications for insurance reimbursement, as well as the need for a greater understanding of orthotic devices and their purpose and function, also indicates the need for further research.

Statement of the Problem

Heel lifts are effective in correcting the length differences in mild LLDs; however, the biomechanical factors that may cause or contribute to the discrepancies are not addressed (Bandy & Sinning, 1986). Abnormal biomechanics that lead to LLDs can also cause other problems or injuries in the lower extremity (Brady et al., 2003; Kilmartin & Wallace, 1994; Marks, 2004). Using only a heel lift to correct LLDs requires further treatment for other problems that may be present. Complexity and inefficiency exist in using several treatment methods in addition to a heel lift to correct LLDs in patients if their problems may be resolved through the use of an orthotic device only. Therefore, the efficacy or nonefficacy of orthotic devices in correcting LLDs should be established.

Purpose of the Study

The purpose of this study was to assess LLD corrections/reductions associated with the insertion of orthotic devices into patients' shoes.

Research Hypotheses

Abnormal foot mechanics have been identified as a potential cause for LLDs (Brady et al., 2003; Hanada et al., 2001), and orthotic devices have been identified as an appropriate method to correct abnormal foot mechanics (Bates, Osternig, Mason, & James, 1979; Kilmartin & Wallace, 1994; McCulloch, Brunt, & Vander Linden, 1993). Three hypotheses will be tested in this study based on this information.

- The number and severity of LLDs present in the patients when measured without orthotic devices will be reduced when the measurements are taken with the patients using orthotic devices.
- No significant difference in correction of LLDs will exist between men and women.
- No significant differences in correction of LLDs will exist between the age groups studied.

Delimitations

The study was delimited to the following parameters:

1. Participants were between the ages of 18 and 45 years.
2. Participants were from the San Francisco Bay Area in California.
3. Participants were volunteers who have a LLD.
4. Participants already had a pair of rigid orthotic devices.
5. All orthotic devices were prescribed by the same podiatrist.
6. The participants were determined to have a LLD through the iliac crest palpation/book correction method for determining and measuring LLDs as administered by the researcher.

Limitations

The study was limited by the following factors:

1. The method of detecting and measuring LLDs allowed for inconsistencies in the measurements.

2. The study included participants with all types of LLDs without differentiating between structural and functional discrepancies.

3. The method of measurement doesn't differentiate between a pelvic rotation and an LLD.

4. The LLD measurements may have been affected by examiner bias.

Definitions

The following terms were used in this thesis and are defined here for clarification.

Heel lift: "[A device] inserted into the shoe of the short leg in order to equalize the lengths of the lower extremity." (Bandy & Sinning, 1986, p. 173)

Iliac crest palpation and book correction method: A method of detecting and measuring LLDs "by palpating the iliac crests in the standing position. . . we then measure the extent of the difference by correcting the [limb length discrepancy] with a book. The book is opened to the number of pages required and is placed under the foot of the shorter leg until the iliac crests are level by palpation. After removing the book, the pages are firmly compressed and this 'correction' of the [limb length discrepancy] is measured." (Hanada et al., 2001, p. 939)

Limb length discrepancy: "Variations in the length of an individual's legs." (Schuit et al., 1989, p. 663)

Anatomic discrepancy: "[A discrepancy] in which an actual bony asymmetry exists somewhere between the head of the femur and mortise of the ankle." (Woerman & Binder-MacLeod, 1984, p. 230)

Functional discrepancy: "[Occurs] as a physiological response to altered mechanics along the kinetic chain anywhere from the foot to the lumbar spine giving the appearance of a short leg when a bony asymmetry in the length of bones might not actually exist." (Woerman & Binder-MacLeod, 1984, p. 230)

Orthotic device: "An orthotic appliance or device is a type of 'shim' placed between the foot and shoe to modify foot position. . . Foot orthotics can be made either of a soft flexible material or a more rigid plastic material." (Bates et al., 1979, p. 338)

Pelvic leveling device: A leveling device with "a bubble level mounted on [a] center support that attaches to two moveable arms." (Gross et al., 1998, p. 287)

Operational Definitions

The following terms were used in this thesis and are defined specific to this study.

Clinically significant limb length discrepancy: Any limb length discrepancy that causes other problems in the lower extremity.

Correction of limb length discrepancy: Treating a LLD so that the discrepancy is eliminated.

Mild limb length discrepancy: A limb length difference of 1 mm to 20 mm between the right and left limbs of the same individual.

Severe limb length discrepancy: A limb length difference of over 20 mm between the right and left limbs of the same individual.

Treatment of limb length discrepancy: Anything done to correct or reduce clinically significant LLDs.

Summary

LLDs are a common problem (Brady et al., 2003; Hanada et al., 2001; Schuit et al., 1989) and occur in varying degrees of severity. Many problems may result from LLDs (Beattie et al., 1990; Bhave et al., 1999; Brady et al., 2003; Hoyle et al., 1991; Schuit et al., 1989; Subotnick, 1981) and, therefore, the discrepancies should be treated if clinically significant. Correction or reduction of LLDs is accomplished through surgery, heel lifts, or orthotic devices, depending on the severity. The use of orthotic devices to correct or reduce LLDs would allow abnormal foot biomechanics to be corrected at the same time (Kilmartin & Wallace, 1994); however a lack of research exists regarding the efficacy of orthotic devices in correcting or reducing LLDs. The need for a greater understanding of orthotic devices and their function and purpose warrants further research. The purpose of this study is to research the ability of orthotic devices to correct LLDs.

Chapter II

Review of Literature

The purpose of this study was to determine the efficacy of orthotic devices in correcting or reducing LLDs. The following review of literature presents the relevant research in the areas of LLDs and orthotic devices as a basis for this study. Most research on LLDs focuses on methods of detecting and measuring discrepancies, or the results of treatment using a heel lift or surgery. Most of the research on orthotic devices concentrates on their effects on foot biomechanics. Research that investigates the treatment of LLDs using orthotic devices is currently lacking.

The review of literature is organized and presented in the following sections for clarity: (1) Magnitude of limb length discrepancies, (2) Methods of measurement and detection of limb length discrepancies, (3) Methods of nonsurgical treatment for limb length discrepancies, (4) Function and purpose of orthotic devices, and (5) Summary.

Magnitude of Limb Length Discrepancies

Little agreement exists among researchers regarding the magnitude of significant LLDs. Subotnick (1981) found that discrepancies of 1/8 inch or more needed treatment when associated with clinical symptoms. In a study by Bandy and Sinning (1986), the authors stated that a discrepancy of 3/16 inch was a large enough difference to cause measurable asymmetry in the lower extremity and, therefore, studied discrepancies greater than or equal to that amount. Bandy and Sinning (1986) also stated that a discrepancy of one inch was very large clinically. Hanada et al. (2001) classified LLDs as small (7-17 mm), medium (18-35 mm), and large (36-53 mm) in their study. Hanada

et al. (2001) also reported that discrepancies of 5 mm or more have been associated with low back or hip pain, but are usually not considered clinically significant.

Methods of Measurement and Detection of Limb Length Discrepancies

Many different methods of measuring LLDs exist. Several studies have been conducted to determine the validity and reliability of these measurement methods (Woerman & Binder-MacLeod, 1984; Beattie et al., 1990; Hoyle et al., 1991; Gross et al., 1998; Hanada et al., 2001). Woerman and Binder-MacLeod (1984) compared five different methods of measuring LLDs. Twenty examiners measured five participants using four different methods of direct measurement and one method of indirect measurement. The direct methods used a tape measure to measure the distance between two bony landmarks on the body. One method measured from the anterior superior iliac spine (ASIS) to the medial malleolus of the ankle. A second method measured from the ASIS to the lateral malleolus of the ankle. A third method measured from the umbilicus to the medial malleolus, and the final direct method measured from the xiphosternum to the medial malleolus. The indirect method of measurement had the examiner palpate the participant's iliac crests while standing. The examiner then looked for asymmetry in the levelness of the iliac crests. When asymmetry was observed, the examiner placed tiles of .125 cm thickness under the participant's short leg until the iliac crests were level. The magnitude of the discrepancy was then calculated using the number of tiles needed to correct it. The examiners' measurements were then compared to x-rays taken of the participants. The results of Woerman and Binder-MacLeod's (1984) study suggests that, of the direct methods of measurement, the measurement from the ASIS to the lateral

malleolus was the most accurate and valid. However, the authors discovered that the indirect method of iliac palpation and block correction was more accurate and valid than any of the direct methods.

A study conducted by Beattie et al. (1990) assessed the validity of using a tape measure to determine LLDs. In their study, one examiner measured 19 participants twice with a measuring tape. Measurements were taken from each participant's ASIS to the medial malleolus with the participant supine on an examination table. The measurements were then compared to measurements taken from x-rays of the participants. Intraclass correlation coefficients (ICC) were used to determine the validity of the measures. While the examiner's first measurements differed significantly from the x-ray measures, the examiner's second measurements agreed considerably more with the x-ray measurements. The best ICC was obtained using a mean of the two measurements for each participant. The authors concluded that if a mean of the two measurements was used, the data obtained using the tape measure appeared to be valid. However, the authors acknowledged that measurements of the participants in a supine position do not reflect discrepancies associated with functional problems of the ankle or foot.

A study by Hoyle et. al (1991) assessed the reliability and comparability of intraexaminer, interexaminer, and interdevice leg length measurements using two examiners' measurements with a tape measure and a Metrecom. Twenty-five participants were included in the study. Each participant was measured from their ASIS to their medial malleolus on each leg while lying supine on an examination table. Each of the two examiners measured each participant twice with each device. The measurements

were then compared between devices and examiners, and intra-class correlation coefficients were calculated. The ANOVAs indicated significant differences in the repeated measurements taken by each examiner using different devices. The authors concluded that interexaminer measurements and interdevice measurements cannot be compared to one another, but that intraexaminer measurements were reliable.

Gross et al. (1998) were also interested in the accuracy of LLD measurement methods. They conducted a study to determine the validity and reliability of using rigid lifts and a pelvic leveling device to assess LLDs. Two examiners measured LLDs for each participant using a pelvic leveling device positioned on the superior and lateral aspects of the iliac crests. When a discrepancy was observed by the tester, rigid lifts of .3175 cm thickness were placed under the participant's short leg until a level state was achieved according to the pelvic leveling device. The magnitude of the discrepancy was then calculated based on the number of lifts needed to achieve the level state. The examiners' measurements were then compared to x-rays taken of the participants, and the data were analyzed to determine the correlation between the clinical and radiographic measurements. Based on the values obtained for the interclass correlation coefficient and the descriptive statistics of the absolute differences, the results of this study indicate that the reliability and validity for the pelvic leveling device method are unacceptable.

A 2001 study by Hanada et al. evaluated the reliability and validity of the iliac crest palpation and book correction method of measuring LLDs. In their study, they induced LLDs in 34 participants who were then measured by two examiners using the iliac crest palpation and book correction method. The measurements taken by the two

examiners were compared to each other to test the interrater reliability of the measurement technique. The measurements taken were then compared to the magnitude of the induced discrepancy to test for validity of the measurement technique. An intraclass correlation coefficient of .98 was obtained for intrarater reliability and .91 for interrater reliability. For construct and concurrent validity, the intraclass correlation coefficient values were .62 and .76 respectively. Based on these values, the results of the study show that the iliac crest palpation and book correction method is highly reliable and moderately valid. Hanada et al. (2001) suggest using this measurement method when there is no history of pelvic deformity and the iliac crests are easily palpable. This indirect method provides a reliable and valid way to detect functional LLDs that may reflect problems at the ankle and/or foot. The book correction technique also allows more precision in measuring the magnitude of the LLD. The reliability and validity of this method, in addition to its ease of administration, make it the most appropriate method of detecting LLDs for use in this study.

Methods of Nonsurgical Treatment for Limb Length Discrepancies

The most common and accepted nonsurgical treatment method for LLDs is the placement of a heel lift into the shoe of the short limb. Bandy and Sinning (1986) studied the kinematic effects of using a heel lift to correct LLDs. Four males with LLDs between 3/16 inch and 3/8 inch were studied, and all participants had been using a heel lift for over one year. Electrogoniometers were attached to each participant to make a continuous record of the movements of the joints. The participants were then recorded while walking and jogging on a treadmill, first with the heel lifts in and then without

them. The results indicated that the insertion of a heel lift caused more symmetrical movement for the maximum angle of hip flexion and for plantarflexion range of motion during the swing phase of gait. However, it caused more asymmetrical range of motion for knee flexion during the swing phase of gait. The implications of these findings are simply that heel lifts should be used as a treatment method on an individual basis and that patients' responses to treatment should be closely monitored.

In 1989, Schuit et al. conducted a study to further research the effects of heel lift treatments for LLDs. The authors studied the ground reaction forces of 18 participants while walking. Measurements were taken of the ground reaction forces of participants before they started using a heel lift, and again three weeks after they started using a heel lift. Ground reaction force measurements were taken as each participant walked across a force platform. Participants were screened for a LLD before and after insertion of the heel lift and, in all cases, greater levelness of the pelvis was achieved with the insertion of a heel lift. The results of this study suggest that ground reaction forces increased with the use of a heel lift. Schuit et al. (1989) cautioned that this increase in ground reaction forces may cause an increase in wear and tear on the joints of those who use heel lifts.

In addition to heel lifts, orthotic devices and forefoot lifts have also been suggested for use in the treatment of LLDs. Subotnick (1981) suggests that for discrepancies of over ½ inch, forefoot lifts of about ½ the thickness of the heel lift should be used. He also states that functional LLDs can be corrected by placing the arches of the foot in the neutral position, which is achieved through the use of orthotic devices. Subotnick's suggestions are based on clinical observations, however, and have not been

drawn from any research. For this reason, it is important to research these suggested methods of treating LLDs.

Function and Purpose of Orthotic Devices

Orthotic devices are widely accepted as effective treatments for many lower extremity injuries; however, only a few studies demonstrate their efficacy in correcting abnormal foot biomechanics. In 1979, Bates et al. conducted a study to investigate the changes in lower extremity mechanics due to orthotic devices. Six runners who had been using rigid orthotic devices for over 1 year participated in the study. Participants were filmed to show foot placement from the rear and lower extremity movement from a lateral view while running on a treadmill. The participants were filmed while running barefoot, with shoes and, finally, with orthotic devices and shoes. A single right foot fall of each participant was then analyzed and evaluated biomechanically. The results of this study showed that there was a significant reduction in foot pronation with the use of an orthotic device. The authors noted that this reduction in pronation was the result of a reorientation of the heel and not the entire leg, and concluded that foot mechanics are affected by orthotic devices.

Fourteen years later, McCulloch et al. (1993) conducted a similar study to investigate the effects of orthotic devices on foot mechanics while walking. Ten individuals who already had rigid or semi-rigid orthotic devices prescribed for lower extremity injury participated in the study. Participants were filmed from the rear and from the right side while walking on a treadmill, first without and then with orthotic devices. The films were then biomechanically analyzed to assess angular motion of each

joint. Based on the results of the study, McCulloch et al. concluded that the use of orthotic devices had positive effects on rearfoot, ankle, and knee motion, including a decrease in foot pronation. The study also demonstrated that orthotic devices normalized improper biomechanics and provided a physical barrier to subtalar movement.

The positive effects of orthotic devices on abnormal foot biomechanics may translate to other problems of the lower extremity, including functional LLDs. The effectiveness of orthotic devices in correcting or reducing functional LLDs resulting from improper biomechanics depends on their ability to control or correct the abnormal motion. The results of the studies conducted on the efficacy of orthotic devices can only be applied to rigid or semi-rigid devices since other types of orthotic devices were not included in the research. Because rigid functional orthotic devices are the most effective type of orthotic device for controlling and correcting improper foot biomechanics (Doxey, 1983; Jordan, 1939; Subotnick, 1975), this study will include only rigid functional orthotic devices prescribed by the same podiatrist.

Summary

The purpose of this chapter was to review the current literature on LLDs and orthotic devices. The literature regarding the measurement and detection of LLDs suggests that indirect methods of measurement are more reliable and valid than direct methods (Brady et al., 2003; Hanada et al., 2001; Woerman & Binder-MacLeod, 1984) and that of the indirect methods, the most reliable and valid is the iliac crest palpation with either block (Brady et al., 2003) or book (Hanada et al., 2001) correction.

Research regarding the use of heel lifts to treat LLDs indicates an ability to correct the discrepancy by adding length to the short limb (Schuit et al., 1989). Several studies, however, showed some negative effects of heel lift treatment (Bandy & Sinning, 1986; Schuit et al., 1989). Current research is consistent in suggesting that the use of heel lifts as a treatment method should be determined by clinical experience and judgment based on the individual patient's circumstances (Bandy & Sinning, 1986; Brady et al., 2003; Schuit et al., 1989). Though little research has been conducted in the area, orthotic devices have been demonstrated to limit excessive pronation of the foot and to reposition the foot to allow for normal joint biomechanics (Bates et al., 1979; McCulloch et al., 1993). While orthotic devices have been suggested as a treatment method for LLDs by several authors (Bandy & Sinning, 1986; Brady et al., 2003; Schuit et al., 1989; Subotnick, 1981), research has yet to be conducted which provides a scientific basis for the efficacy of correcting or reducing LLDs with orthotic devices.

Chapter III

Methods

In this study, LLDs were measured in participants with and without the use of orthotic devices to determine the efficacy of orthotic devices in correcting or reducing LLDs. This chapter gives a detailed explanation of the methods and procedures used by the researcher. A description of the pilot study, participants, instrumentation, research design, and data analysis are included. A summary concludes the chapter.

Pilot Study

A pilot study was conducted to determine the reliability of the examiner and test the research protocol. The pilot study included seven participants, male and female, over the age of 18. The participants were solicited from the examiner's peers. The participants were examined and measured for a limb length discrepancy using the iliac crest palpation and book correction method as described by Hanada et al. (2001). Each participant was instructed to remove his or her shoes and to stand upright with feet shoulder width apart. The researcher crouched in front of the participant so that her eyes were at the level of the participant's iliac crests as she palpated them to look for a limb length discrepancy. The researcher then placed the book under the participant's short leg, and adjusted the number of pages until the appropriate height was identified and the participant's iliac crests were level upon palpation. The participant then stepped off the book and the researcher used a metric ruler to measure the height of the book at the number of pages required to level the participant's iliac crests. The measurement was performed three times on each participant with the first measurement being performed on

all participants, followed by the second measurement being performed on all participants, and finally the third measurement was performed on all participants. The results were then analyzed to determine the reliability of the examiner.

Participants

The study included 19 participants, 6 men and 13 women. One female participant was excluded from the study because of pregnancy. The participants were between the ages of 18 and 45 years. The age range was based on literature which indicated that spinal misalignment due to a LLD was seldom corrected through intervention in the older population (Brady et al., 2003). Overweight and obese participants were excluded from the study because of the effect obesity has on measurement of LLDs (Hanada et al., 2001; Woerman & Binder-MacLeod, 1984). Participants whose ASIS was not palpable because of overlying adipose tissue were considered overweight/obese for the purposes of this study and were excluded from participation. All participants were prescribed custom orthotic devices for a reason other than a LLD. All of the orthotic devices prescribed were custom made rigid devices with a rearfoot post because those are the most effective devices for controlling and correcting improper biomechanics. Following approval from the San Jose State University Human Subjects-Institutional Review Board (see Appendix A), individuals interested in participating in the study were solicited from the podiatry office of David R. Francis, DPM. Each participant signed a consent form (see Appendix B) agreeing to participate and completed a questionnaire regarding the use of orthotic devices and orthopedic health history (see Appendix C). Potential participants were screened for the presence of a LLD by the researcher using the iliac

crest palpation method as described by Woerman and Binder-MacLeod (1984). The participant screening took place in the office of David R. Francis, DPM or in the home of the participant. Individuals with a LLD detected through the iliac crest palpation method were included in the study. Following the screening, participants were assigned an identification number and measured for the study.

Instrumentation

The method of measurement used in this study was the iliac crest palpation and book correction method as described by Hanada et al. (2001). Iliac crest palpation with either book or block correction has been identified as the most reliable and valid method of clinical assessment for LLD by several authors (Brady et al., 2003; Hanada et al., 2001; Woerman & Binder-MacLeod, 1984). Book correction was chosen for use in this study because it allows more sensitivity in measurement than block correction. Measurement equipment (see Figure 1) included a book that was approximately 2 cm in thickness and larger than the feet of the participants and a metric ruler that measured in millimeters.

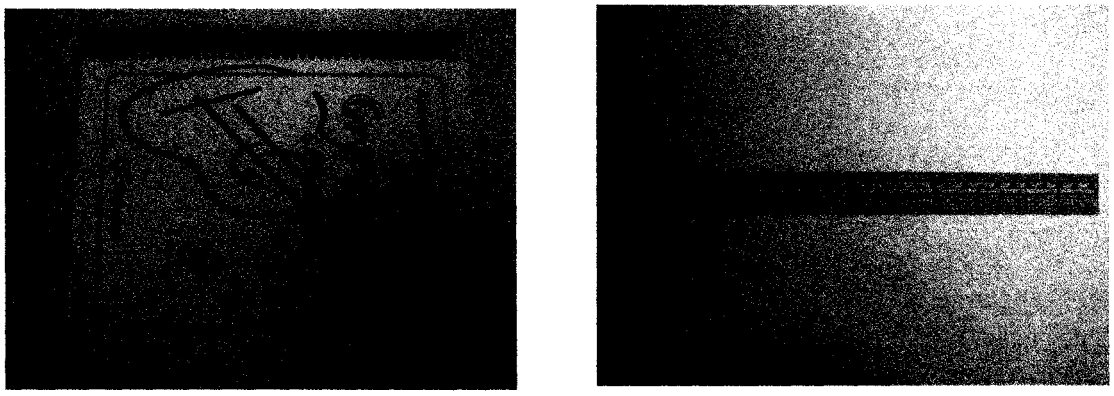


Figure 1. Research Instrumentation

Participants' measurements were recorded in millimeters on the Limb Length Discrepancy Measurement Sheet (see Appendix D).

Research Design

Participants were measured either in the office of David R. Francis, DPM or in their homes. Approximately 10 to 15 minutes were needed to complete measurements on each participant. Measurements were taken to determine the magnitude of the participant's LLD with no shoes or orthotic devices, with shoes, and with shoes and orthotic devices. These measurements were taken in a different order for each participant. Every third participant beginning with participant one was measured first with no shoes or orthotic devices, then with shoes and orthotic devices, and then with shoes only. Every third participant beginning with participant two was measured first with shoes only, followed by no shoes or orthotic devices, and then with orthotic devices and shoes. Every third participant beginning with participant three was measured first with shoes and orthotic devices, then with shoes only, and then with no shoes or orthotic devices.

Figure 2. Iliac Crest Palpation to Detect a LLD

Each participant was instructed to remove his or her shoes and to stand upright with feet shoulder width apart. The researcher crouched in front of the participant so that her eyes were at the level of the participant's iliac crests as she

palpated the iliac crests to look for a LLD (see Figure 2). The researcher then placed the book under the participant's short leg, and adjusted the number of pages until the appropriate height was found and the participant's iliac crests were level upon palpation. The participant then stepped off the book, and the researcher used the metric ruler to measure the height of the book at the number of pages required to level the participant's iliac crests. The measurement was then recorded on the measurement sheet as the magnitude of the participant's LLD without shoes or orthotic devices.

For the measurement with shoes only, the participant's shoes were replaced on his or her feet without the orthotic devices, and the participant was instructed to stand upright with feet shoulder width apart. The researcher again crouched in front of the participant so her eyes were at the level of the participant's iliac crests. She palpated the iliac crests to determine if a LLD was present. If a discrepancy was present, the researcher placed the book under the participant's shoe and turned the pages until the appropriate height was reached and the participant's iliac crests were level (see Figure 3). The participant then stepped off the book, and the researcher measured the height of the book at the number of pages needed to correct the discrepancy. This measurement was recorded on the

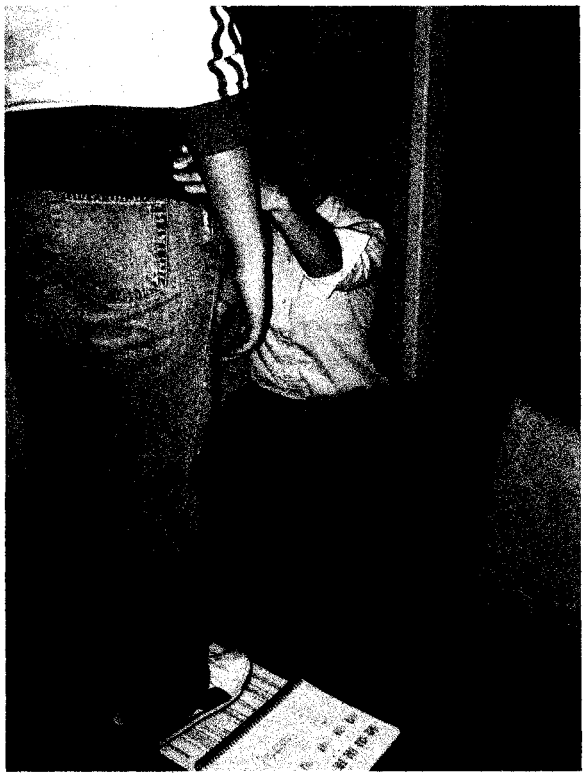


Figure 3. Iliac Crest Palpation with Book Correction.

measurement sheet as the magnitude of the participant's limb length discrepancy with the use of shoes only.

For the measurement with shoes and orthotic devices, the participant's orthotic devices were placed inside the participant's shoes and the shoes placed on the participant's feet. The participant was instructed to stand upright with feet shoulder width apart. The researcher again crouched in front of the participant so her eyes were at the level of the participant's iliac crests. She palpated the iliac crests to determine if a LLD was present. If a discrepancy was present, the researcher placed the book under the participant's shoe and turned the pages until the appropriate height was reached and the participant's iliac crests were level. The participant then stepped off the book, and the researcher measured the height of the book at the number of pages needed to correct the discrepancy. This measurement was recorded on the measurement sheet as the magnitude of the participant's limb length discrepancy with the use of orthotics. If there was no LLD noted following the use of the orthotic devices, it was so recorded on the measurement sheet.

Analysis of Data

The purpose of this study was to investigate the efficacy of orthotic devices in correcting or reducing LLDs. Orthotic devices are hypothesized to correct or reduce LLDs that are caused by abnormal foot biomechanics. The data were analyzed to assess the number of LLDs that were successfully corrected with the use of orthotic devices, as well as the number of discrepancies that were reduced in magnitude with the use of orthotic devices, the number of discrepancies that had no change in magnitude with the

use of orthotic devices, and the number of discrepancies that increased in magnitude with the use of orthotic devices. The amount of reduction in the magnitude of the discrepancy was also analyzed. The data analysis also included age and gender variables; thus, a two-factor ANOVA was employed to test for significant differences due to age and gender. The data were grouped in three age ranges: 18-26 years, 27-36 years, and 37-45 years. A simple ANOVA and a repeated measures ANOVA were used to test for significant differences between the three measurements performed on each participant. A Scheffé post hoc test was performed on the simple ANOVA and a Tukey post hoc test was used on the repeated measures ANOVA to determine where the significant differences existed. For all analyses, $p < .05$.

Summary

The purpose of this chapter was to describe the methods and procedures that were used in this research study. The participants were chosen according to criteria from other studies in this area. The study was approved by the SJSU-IRB, and all participants provided consent. The instrumentation used in the study was those items needed for measuring and recording the participants' LLDs. The research design included the measurement of the participants' LLDs without shoes, with shoes only, and with orthotic devices and shoes. Analyses of variance were used to evaluate LLDs measured under these three conditions.

Chapter IV

Results

While orthotic devices have been suggested as a possible method of treating LLDs (Bandy & Sinning, 1986; Brady et al., 2003; Subotnick, 1981), establishment as an effective treatment method through research has yet to be done. The purpose of this study was to assess the efficacy of orthotic devices in correcting LLDs. Orthotic devices are used to correct improper foot biomechanics. Since improper biomechanics may induce a LLD (Brady et al., 2003; Kilmartin & Wallace, 1994; Marks, 2004), correction of those improper biomechanics through the use of an orthotic device is theorized to reduce or correct LLDs which are caused by abnormal foot motion.

A pilot study was conducted to determine the reliability of the examiner and to test the research protocol. No problems were encountered with the protocol during the pilot study, and the reliability of the examiner was established with an intraclass correlation (R) of .93. The pilot study was useful in further familiarizing the examiner with the measurement procedures and increasing reliability.

Orthotic devices were hypothesized to correct or reduce LLDs caused by improper biomechanics of the foot. The data were analyzed to determine the level of LLD correction or reduction obtained with the use of orthotic devices. The data collected were grouped according to the participant's gender and age, and LLD reductions were then calculated. A two-factor ANOVA (Gender x Age) was used to analyze for interactions based on age and gender. LLD corrections and reductions were analyzed using a simple ANOVA and a Scheffé post hoc test with $p<.05$, as well as a repeated

measures ANOVA with a Tukey post hoc test with $p<.05$. The statistical results of the analyses are presented in this chapter, followed by a summary.

Statistical Results

Data were collected from 20 participants (6 males and 14 females) with a LLD. One female participant was excluded from the study because of pregnancy, leaving 13 females. All participants were measured 3 times, once with no shoes or orthotic devices, once with shoes only, and once with shoes and orthotic devices to determine the magnitude of the LLD. Measurements were analyzed to evaluate changes in the magnitude of the discrepancy with the use of orthotic devices. Of the 19 participants in the study, three participants' LLDs were corrected with the use of orthotic devices, 10 were reduced in magnitude, two had no change in magnitude, two increased in magnitude, and two participants' LLDs were switched to the other leg (see Table 1).

Table 1.

Summary of LLD Changes

Status of LLD	*No. of Participants*	*Gender*	*Age Group*[a]
Corrected	3	2 M, 1 F	1 grp 1, 1 grp 2, 1 grp 3
Reduced	10	3 M, 7 F	2 grp 1, 5 grp 2, 3 grp 3
No Change	2	2 F	2 grp 1
Increased	2	2 F	2 grp 2
Switched to other leg	2	1 M, 1 F	1 grp 1, 1 grp 3

[a] Group 1=18-26 years, Group 2=27-36 years, Group 3=37-45 years

A two-way ANOVA was performed to determine the existence of significant differences between gender and age groups for the change in discrepancy magnitude between the barefoot and the shoes with orthotics measurements. The alpha level was preset at 0.05. No significant differences existed between gender or age groups for any of the three measurements. The two-way ANOVA summary for the gender and age groups is presented in table 2. No post hoc test was performed for the gender and age group two-way ANOVA because there were no significant differences.

Table 2.

2-way ANOVA (gender, age)

Source	*SS*	*df*	*MS*	*F*	*Sig*
Age	8.33	2	4.16	1.01	0.392
Gender	8.67	1	8.67	2.1	0.171
Age*Gender	8.26	2	4.13	1	0.395
Error	53.79	13	4.14		
Total	179.25	19			
Corrected Total	84.18	18			

A simple ANOVA performed on the three sets of LLD measurements indicated significant differences between the measurements with no shoes or orthotic devices, with shoes only, and with shoes and orthotic devices. The results of this ANOVA were $F(2,54) = 10.35, p<.05$ (see Tables 3 & 4). A Scheffé post hoc test was conducted, indicating a significant difference between the barefoot measurements compared to the

measurements with shoes and orthotic devices and between the measurements with shoes and with shoes and orthotic devices. However, no significant difference occurred between the barefoot measurements and the measurements with shoes.

Table 3.

Summary of Measurements of Limb Length Discrepancies

Groups	*Count*	*Sum*	*Average*	*Variance*
Barefoot	19	70	3.68	1.39
Shoes	19	60	3.16	1.89
Orthotics	19	27.5	1.45	4.25

Table 4.

ANOVA Results for LLD Measurements

Source	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	51.97	2	25.99	10.35	0.00016	3.17
Within Groups	135.58	54	2.51			
Total	187.55	56				

A repeated measures ANOVA was also conducted on the three sets of LLD measurements. The normality test failed and a Friedman repeated measures ANOVA on Ranks was conducted. A significant difference was indicated and a Tukey post hoc test was performed to determine where the significant differences existed. The post hoc test indicated that significant differences existed between the barefoot measurements and the

shoes with orthotic device measurements and between the shoes only measurements and the shoes and orthotic device measurements. As with the simple ANOVA, no significant difference was indicated between the barefoot measurements and the measurements with shoes.

Summary

The data were analyzed for significance using a two-way ANOVA for gender and age effects and a simple ANOVA and a repeated measures ANOVA with post hoc tests for differences between LLD measurements. Thirteen of the 19 participants demonstrated a reduction or correction of the LLD. The two-way ANOVA indicated no significant difference between gender or age groups. The simple ANOVA and repeated measures ANOVA with post hoc tests showed significant differences between the three LLD measurement groups, specifically between the barefoot measurements and the measurements with shoes and orthotics, and between measurements with shoes only and with shoes and orthotics.

Chapter V

Discussion and Conclusions

LLDs are common in today's population (Brady et al., 2003; Hanada et al., 2001; Schuit et al., 1989). Varying degrees of discrepancies exist, but any magnitude of LLD could lead to problems in the lower extremity (Beattie et al., 1990; Bhave et al., 1999; Brady et al., 2003; Hoyle et al., 1991; Subtonick, 1981). Currently, LLDs are most often treated with a heel lift in the shoe of the short leg. Orthotic devices have been suggested by several researchers as a treatment method for LLDs (Bandy & Sinning, 1986; Brady et al., 2003; Subotnick, 1981), but a lack of research exists in that area to demonstrate their efficacy. By limiting abnormal mechanics of the foot, orthotic devices may be effective in treating LLDs that result from improper biomechanics of the foot.

This study addressed the efficacy of rigid orthotic devices in the correction or reduction of LLDs. Functional LLDs were hypothesized to be reduced or corrected with the use of orthotic devices, but age and gender were hypothesized to have no impact on changes in LLD magnitude. Nineteen participants with LLDs were measured barefoot, with shoes only, and with shoes and rigid orthotic devices to determine the magnitude of their discrepancies under each condition. The data were analyzed using a two-way ANOVA, a simple ANOVA with a Scheffé post hoc test, and a repeated measures ANOVA with a Tukey post hoc test where $p<.05$. Age and gender variables were also considered in the analysis.

Discussion

The results of this study suggest that the use of rigid orthotic devices significantly affected the magnitude of LLDs. Age and gender were not shown to have a significant effect on LLDs. Of the 19 participants in the study, 13 experienced a correction or reduction of their LLD with the use of orthotic devices. Two participants' orginal LLD was corrected, but a LLD was induced on their other leg with the use of orthotic devices. Two participants had no change in their LLD with the use of orthotic devices, and two participants experienced an increase in the magnitude of their LLD with the use of their orthotic devices. The results of the simple ANOVA and the repeated measures ANOVA demonstrated a significant difference in the means of each of the three measurements. These results indicate that rigid orthotic devices have a significant effect on LLDs. This supports the suggestions of Bandy and Sinning (1986), Brady et. al (2003), and Subotnick (1981) for the use of orthotic devices in correcting or treating LLDs.

Orthotic devices cannot be worn without shoes, so measurements with the orthotic devices included the participants' shoes. It was necessary to include measurements with shoes only to assess how much of the correction or reduction was a result of the orthotic device and how much was a result of the shoe. The Scheffé and Tukey post hoc tests demonstrated that significant differences in the measurements occurred between the measurements with no shoes and with shoes and orthotic devices, and between measurements with shoes and with shoes and orthotic devices. No significant difference existed between the measurements with no shoes and the measurements with shoes only.

This indicates that most of the correction or reduction in the magnitude of the LLD was due to the use of the orthotic device and not the shoe.

Abnormal biomechanics of the foot have been suggested as a possible cause of LLDs (Brady et al., 2003; Kilmartin & Wallace, 1994; Marks, 2004). By correcting improper mechanics that may be causing a LLD, theoretically the LLD should be corrected or reduced. Orthotic devices have been used for years to correct abnormal mechanics of the foot. By correcting abnormal mechanics in the foot, orthotic devices should, theoretically, also correct or reduce the resulting LLD. That theory is supported by the results of this study. The results also support the researcher's hypotheses that age and gender would have no effect on LLD magnitude, but that LLDs would be reduced in magnitude and/or frequency with the use of orthotic devices. The results also support clinical observations regarding the effects of orthotic devices on LLDs as mentioned by Subotnick (1981).

Unfortunately, there are limitations of this study. Anatomical discrepancies were not excluded from the study because of the cost of differentiating them from functional discrepancies. In addition, anatomical and functional discrepancies may exist together. In that case, although an anatomical discrepancy may be present, orthotic devices may still be effective in reducing or correcting the existing functional discrepancy. Future research in this area could use x-rays to identify and differentiate anatomical discrepancies to exclude them from the research.

In addition, the sample size was small. To have uniformity in orthotic device prescriptions, all participants were patients of one doctor. This limited the available

participant pool. The sample size was comparable to other studies in this area (Beattie et al., 1990; Bhave et el., 1999; McCulloch et al., 1993; Schuit et al., 1989), but statistical power and generalizability of the study would be strengthened with a larger sample size. The statistical power of the study is not sufficient to make significant conclusions regarding gender and age variables. While difficult to generalize the results of the measurements, the results are sufficient to warrant further investigation and research.

Steps were taken to limit the effects of examiner inexperience, bias, and inconsistency in the measurements of LLDs in this study. A pilot study was conducted to familiarize the examiner with the research protocol and identify any existing problems or difficulties in the proposed research methods. The measurements were also taken in a different order for each participant, thus limiting examiner bias. Throughout the study, the measurement methods and the measurements taken were perceived to be accurate and valid by the examiner.

The results of the study indicate positive effects of orthotic devices on functional problems of the lower extremity, particularly LLDs. This supports the findings of McCulloch et al. (1993) which indicated positive effects of orthotic devices on lower extremity biomechanics that may have contributed to problems or injuries. The findings of this study warrant further research into the effects of orthotic devices on foot biomechanics and how that may alter the biomechanics of the other joints of the lower extremity. Further research in this area would help to evaluate the efficacy of orthotic devices in treating other problems of the lower extremity in addition to correcting or reducing LLDs. It would also be beneficial to further investigate the relationship

between abnormal biomechanics of the foot and the presence of LLDs. Orthotic devices are a more expensive alternative to heel lifts or shoe inserts, but can be more effective for LLDs caused by abnormal mechanics of the foot. Further research in the area will also help to build a case for insurance reimbursement for orthotic devices. This would make it easier for people to obtain and benefit from orthotic devices.

Conclusions

Results of the study demonstrate a significant difference between LLD measurements with and without rigid orthotic devices. Based on the results, it can be concluded that the orthotic devices have a significant effect on LLDs and should be considered as a possible method of treatment for LLDs that result from abnormal biomechanics of the foot. Additional research to investigate the relationships between orthotic devices and LLDs is warranted based on the findings of this study.

No significant differences existed in measurements when analyzed for gender or age variables. There were more women than men in the study and there were unequal numbers of participants in the three age groups. The orthotic devices were more effective than shoes only in correcting/reducing LLDs. This may indicate additional effects of orthotic devices on correcting or reducing LLDs over shoes alone and supports their use in treating lower extremity problems associated with LLDs.

Not all of the LLDs measured in the study were positively affected by the orthotic devices. It is, therefore, necessary to consider the circumstances of each individual's LLD in determining the method of treatment to be used. Orthotic devices may not be appropriate for individuals with anatomical LLDs. The results of this study indicate that

orthotic devices should not be overlooked as a possible treatment method of limb length discrepancies. In treating LLDs, practitioners should evaluate each individual and the circumstances regarding their LLD. Biomechanics of the foot should be considered, as well as the presence of other problems in the lower extremity. Based on the examiner's findings, a treatment method should be chosen that will address as many problems as possible that are present in the individual's LLD.

Suggestions for Future Research

Future research in this area should differentiate between functional and anatomical discrepancies as well as evaluate biomechanical changes in the lower extremity associated with the use of orthotic devices. Age and gender variables may also be further researched by including equal numbers of males and females and by including equal numbers of participants in each age group. Additional research might also investigate the effects of orthotic devices on LLDs over time and the effects of orthotic devices on other lower extremity problems associated with LLDs.

References

Bandy, W. D. & Sinning, W. E. (1986). Kinematic effects of heel lift use to correct lower limb length differences. *Journal of Orthopaedic and Sports Physical Therapy, 7,* 173-179.

Bates, B. T., Osternig, L. R., Mason, B., & James, L. S. (1979). Foot orthotic devices to modify selected aspects of lower extremity mechanics. *American Journal of Sports Medicine, 7,* 338-342.

Beattie, P., Isaacson, K., Riddle, D. L., & Rothstein, J.M. (1990). Validity of derived measurements of leg length differences obtained by use of a tape measure. *Physical Therapy, 70,* 150-158. Retrieved November 19, 2005 from Expanded Academic ASAP.

Bhave, A., Paley, D., & Herzenberg, J. E. (1999). Improvements in gait parameters after lengthening for the treatment of limb-length discrepancy. *Journal of Bone and Joint Surgery, 81,* 529-534.

Brady, R. J., Dean, J. B., Skinner, T. M., & Gross, M. T. (2003). Limb length inequality: Clinical implications for assessment and intervention. *Journal of Orthopaedic and Sports Physical Therapy, 33,* 221-234.

Doxey, G. E. (1983). The semi-flexible foot orthotic: Fabrication and guidelines for use. *Journal of Orthopaedic and Sports Physical Therapy, 5,* 26-29.

Gross, M. T., Burns, C. B., Chapman, S. W., Hudson, C. J., Curtis, H. S., Lehmann, J. R. et al. (1998). Reliability and validity of rigid lift and pelvic leveling device method in assessing functional leg length inequality. *Journal of Orthopaedic and Sports Physical Therapy, 27,* 285-294.

Hanada, E., Kirby, R. L., Mitchell, M., & Swuste, J. M. (2001). Measuring leg-length discrepancy by the "iliac crest palpation and book correction" method: Reliability and validity. *Archives of Physical Medicine and Rehabilitation, 82,* 938-942.

Heiderscheit, B., Hamill, J., & Tiberio, D. (2001). A biomechanical perspective: Do foot orthoses work? *British Journal of Sports Medicine, 35,* (4).

Hoyle, D.A., Latour, M., & Bohannon, R.W. (1991). Intraexaminer, interexaminer, and interdevice comparability of leg length measurements obtained with measuring tape and metrecom. *Journal of Orthopaedic and Sports Physical Therapy, 14,* 263-268.

Jordan, H. H. (1939). *Orthopedic appliances.* New York: Oxford University Press.

Kilmartin, T. E. & Wallace, W. A. (1994). The scientific basis for the use of biomechanical foot orthoses in the treatment of lower limb sports injuries - a review of literature. *British Journal of Sports Medicine, 28,* 180-184.

Marks, R. (2004). Orthoses wedge their way into OA treatment – a lateral wedge may realign the bones of the lower leg to decrease load on the medial compartment of the knee. *Biomechanics, August 1,* p49. Retrieved September 18, 2004, from Expanded Academic ASAP.

McCulloch, M. U., Brunt, D., & Vander Linden, D. (1993). The effect of foot orthotics and gait velocity on lower limb kinematics and temporal events of stance. *Journal of Orthopaedic and Sports Physical Therapy, 17,* 2-10.

Schuit, D., Adrian, M., & Pidcoe, P. (1989). Effect of heel lifts on ground reaction force patterns in subjects with structural leg-length discrepancies. *Physical Therapy, 69,* 663-671.

Segedy, A. & Edwards, A. R. (2003). Foot orthoses. *Biomechanics, July 1,* p33. Retrieved September 26, 2004, from Expanded Academic ASAP.

Subotnick, S. I. (1975). *Podiatric sports medicine.* New York: Futura Publishing Company.

Subotnick, S. I. (1981). Limb length discrepancies of the lower extremity (The short leg syndrome). *Journal of Orthopaedic and Sports Physical Therapy, 3,* 11-16.

Woerman, A. L. & Binder-MacLeod, S. A. (1984). Leg length discrepancy assessment: Accuracy and precision in five clinical methods of evaluation. *Journal of Orthopaedic and Sports Physical Therapy, 5,* 230-239.

Appendix A

Approval from the San Jose State University Human Subjects-Institutional Review Board

San José State
UNIVERSITY

Office of the Provost
Associate Vice President
Graduate Studies & Research

One Washington Square
San José, CA 95192-0025
Voice: 408-924-2427
Fax: 408-924-2477

E-mail: gradstudies@sjsu.edu
http://www.sjsu.edu

To: Jenni Jespersen
1541 Nuthatch Ln.
Sunnyvale, CA 94087

From: Pam Stacks, Ph.D.
AVP, Graduate Studies & Research

Date: January 17, 2006

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

"Orthotic Devices in the Treatment of Limb Length Discrepancies"

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to all data that may be collected from the subjects. The approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Pam Stacks, Ph.D. immediately. Injury includes but is not limited to bodily harm, psychological trauma, and release of potentially damaging personal information. This approval for the human subject's portion of your project is in effect for one year, and data collection beyond January 17, 2007 requires an extension request.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services that the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2480.

Cc: Greg Payne - 0054

Appendix B

Participant Consent Form

San José State
UNIVERSITY

College of Applied Sciences and Arts

Department of Kinesiology

One Washington Square
San José, CA 95192-0054
Voice: 408-924-3010
Fax: 408-924-3053

Consent Form (for Adult Participants)

Agreement to Participate in Research

Responsible Investigator(s): _Jenni Jespersen, ATC_____
Title of Protocol: _Orthotic Devices in the Treatment of Limb Length Discrepancies__

1. You have been asked to participate in a research study investigating the effectiveness of using orthotic devices to treat limb length discrepancies.
2. You will be measured for a limb length discrepancy three times, with no shoes or orthotics, with shoes, and with shoes and orthotics at the office of David R. Francis, DPM. A book and metric ruler will be used to determine the magnitude of the limb length discrepancy.
3. No risks are anticipated from participation in this study.
4. There are no discernable benefits expected from participation in this study.
5. There are no alternative procedures.
6. Although the results of this study may be published, no information that could identify you will be included.
7. There will be no compensation rewarded for participation in this study.
8. Questions about this research may be addressed to Jenni Jespersen, 408-718-4740. Complaints about the research may be presented to Greg Payne, Department Chair, Kinesiology Department, 408-924-3028. Questions about research subjects' rights or research-related injury may be presented to Pamela Stacks, Ph.D., Associate Vice President, Graduate Studies and Research, at (408) 924-2480.
9. No service of any kind, to which you are otherwise entitled, will be lost or jeopardized if you choose to "not participate" in the study.
10. Your consent is being given voluntarily. You may refuse to participate in the entire study or in any part of the study. If you decide to participate in the study, you are free to withdraw at any time without any negative effect on your relations with San Jose State University or with any other participating institutions or agencies.
11. At the time that you sign this consent form, you will receive a copy of it for your records, signed and dated by the investigator.

The signature of a subject on this document indicates agreement to participate in the study.
The signature of a researcher on this document indicates agreement to include the above named subject in the research and attestation that the subject has been fully informed of his or her rights.

_____	_____
Subject's Signature	Date
_____	_____
Investigator's Signature	Date

Appendix C

Participant Questionnaire

Name:

Age: Height: Weight: Sex:

Do you have a known leg length discrepancy?

If yes, do you have any symptoms/problems because of it?

Who prescribed your current pair of orthotics?

How long have you been using orthotics?

Have you had/do you have any injuries to your lower extremities (legs or low back)?

If yes, please describe below:

Do you exercise regularly?

If yes, please describe the type and frequency of physical exercise:

Appendix D

Limb Length Discrepancy Measurement Sheet

Participant number	Measurement without orthotic device	Measurement with shoes only	Measurement with shoes and orthotic devices

Appendix E

Pilot Study Data

Participant No.	Measurement #1	Measurement #2	Measurement #3
1	5 mm (right)	6 mm (right)	5.5 mm (right)
2	2 mm (left)	3 mm (left)	3 mm (left)
3	2 mm (left)	2 mm (left)	3 mm (left)
4	3 mm (left)	4 mm (left)	4 mm (left)
5	2 mm (right)	2 mm (right)	1.5 mm (right)
6	3 mm (right)	3 mm (right)	4 mm (right)
7	2 mm (left)	3 mm (left)	3 mm (left)

Appendix F

Raw Data

Participant	Gender	Age	Discrepancy w/ no shoes or orthotics	Dscpy w/ Shoes only	Dscpy w/ Shoes and Orthotics
1	F	34	2mm (L leg)	3mm (L)	5mm (L)
2	F	34	3mm (R leg)	3mm (R)	1.5mm (R)
3	F	23	2mm (R leg)	2mm (R)	2mm (R)
4	F	20	4mm (R leg)	3mm (R)	2mm (R)
5	F	26	3mm (R leg)	5mm (R)	3mm (R)
6	M	32	4mm (R leg)	3mm (R)	2mm (R)
7	F	36	2mm (R leg)	2mm (R)	2.5mm (R)
8	F	18	3mm (R leg)	2.5mm (R)	0mm
9	F	39	3mm (L leg)	3.5mm (L)	4mm (R)
10	F	24	6.5mm (L leg)	7.5mm (L)	4.5mm (L)
11	F	33	5mm (R leg)	3mm (R)	2mm (R)
12	M	33	4mm (L leg)	2.5mm (L)	0mm
13	M	18	2.5mm (R leg)	1mm (R)	2mm (L)
14	F	36	4mm (R leg)	2mm (R)	1mm (R)
15	M	38	4mm (R leg)	3mm (R)	2mm (R)
16	M	32	5mm (R leg)	3mm (R)	2mm (R)
17	F	45	4mm (L leg)	3mm (L)	1.5mm (L)
18	M	41	4.5mm (L leg)	4.5mm (L)	0mm
19	F	42	4.5mm (L leg)	3.5mm (L)	2.5mm (L)