

YVONNE M. GOLIGHTLY, PT, MS¹ • JEREMIAH J. TATE, PT, MS²
 CHARLES B. BURNS, MSPH, RT(R), DABR³ • MICHAEL T. GROSS, PT, PhD⁴

Changes in Pain and Disability Secondary to Shoe Lift Intervention in Subjects With Limb Length Inequality and Chronic Low Back Pain: A Preliminary Report

Low back pain (LBP) is a considerable health and socioeconomic problem affecting 70% to 80% of adults at some time in their lives.¹² LBP is the most frequent cause of activity limitation in individuals younger than 45 years and is the second most common reason for doctor visits in the United States.¹ Over \$25 billion is spent annually to treat LBP, not including the additional societal costs associated with time away from work and disability.⁷ Identifying

factors associated with LBP is important to aid in the development and implementation of effective treatments at lower financial cost.

Previous reports have suggested that limb length inequality (LLI) may be a

cause of LBP. Common strategies used to compensate for LLI (pelvic tilt in the frontal plane,^{4,5,10,14,23,27} functional scoliosis,^{4,5,10,14,23,27} and sacroiliac dysfunctions^{4,9}) may contribute to the development of, or exacerbate, LBP. Gofton¹⁶ reported that

patients with LLI frequently noted increasing pain while standing for 20 to 30 minutes, followed by immediate relief upon sitting. Rush and Steiner,²⁷ Giles and Taylor,¹⁵ and Friberg¹⁴ reported a higher prevalence of LLI in individuals with LBP compared to control subjects.

Other investigators, however, have reported no association between LLI and LBP.^{18,20,22,29} Soukka et al²⁹ reported that factory workers with LBP and factory workers without LBP had similar distributions of LLI up to 10 mm. Grundy and Roberts¹⁸ determined no statistically significant differences in LLI between subjects with chronic LBP and a control group matched by age and sex. These studies did not account for other pathological conditions of the lower extremities. Subjects, therefore, may have compensated for their LLI at various levels throughout the lower extremity. These compensations may have minimized the effect of the LLI in the lumbopelvic region. In addition, 2 of the studies^{18,22} used clinical measures to detect LLI. Clinical methods to detect LLI, however, may have less than desirable reliability and validity.¹⁷

Further evidence to support the association between LLI and LBP is provided by studies incorporating the use of shoe lifts.^{14-16,19,21,23,24,28} Nichols²³ reported that all of his subjects with LBP and LLI not-

● **STUDY DESIGN:** Preassessment and postassessment of treatment intervention.

● **OBJECTIVE:** To determine the changes in pain and disability secondary to shoe lift intervention for subjects with chronic low back pain (LBP) who have a limb length inequality (LLI).

● **BACKGROUND:** Previous reports have suggested that LLI may be a cause of LBP. Most prior studies of lift therapy for management of LLI in patients with LBP have lacked clear guidelines for clinicians regarding the implementation of shoe lift intervention.

● **METHODS AND MEASURES:** Twelve subjects (6 male, 6 female) between the ages of 19 and 62 years with LLI (6.4-22.2 mm) and chronic LBP (1-30 years) participated. Visual analog scale pain ratings and disability questionnaire scores were acquired before and after lift intervention. Subjects determined their lift height based on

resolution of LBP symptoms.

● **RESULTS:** Subjects experienced relief of general pain symptoms ($P = .0006$) and pain associated with standing ($P = .002$) following lift intervention, with minimally clinically important (MCID) reductions in general pain for 9 of 12 subjects and MCID reductions in standing pain for 8 of 10 subjects. Subjects also had less disability on the disability questionnaire ($P = .001$) following the intervention, with 9 of 12 subjects experiencing MCID reductions in disability.

● **CONCLUSION:** Shoe lifts may reduce LBP and improve function for patients who have chronic LBP and an LLI. Randomized controlled trials are needed to assess the efficacy of this intervention. *J Orthop Sports Phys Ther* 2007;37(7):380-388. doi:10.2519/jospt.2007.2429

● **KEY WORDS:** leg length inequality, low back pain, rehabilitation

¹Research Physical Therapist, Durham Veterans Affairs Medical Center, Durham, NC. ²Adjunct Instructor, Department of Physical Therapy, University of Tennessee at Chattanooga, Chattanooga, TN. ³Associate Professor, Division of Radiologic Science, University of North Carolina at Chapel Hill, Chapel Hill, NC. ⁴Professor, Center for Human Movement Science, Division of Physical Therapy, University of North Carolina at Chapel Hill, Chapel Hill, NC. This research was completed in partial fulfillment of Ms Golightly's and Mr Tate's Master of Science degrees in the Program in Human Movement Science, University of North Carolina at Chapel Hill. The protocol for this study was approved by the Biomedical Internal Review Board and the Radiation Safety Committee at The University of North Carolina at Chapel Hill. Address correspondence to Dr Michael T. Gross, CB# 7135, 3034 Bonurant Hall, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-7135. E-mail: mtgross@med.unc.edu

ed subjective improvement in their LBP following use of shoe lifts, while Gofton¹⁶ reported that his subjects all had major or complete relief of pain with this intervention. Giles and Taylor¹⁵ reported that symptoms for subjects with LBP and LLI generally improved with shoe lifts. Friberg¹⁴ reported that 75% of subjects with LBP and LLI were symptom free and 16% reported some pain alleviation after shoe lift therapy. Defrin et al¹¹ reported that lift correction of LLI less than 10 mm resulted in significant reductions in pain intensity and disability. Several other investigators have also reported that subjects with LLI experienced relief of LBP following intervention with lift therapy.^{18,21,24,29}

Previous lift studies have varied in the total amount of lift correction used when treating patients with an LLI and LBP. Giles and Taylor¹⁵ utilized shoe or heel lifts equal to the magnitude of LLI as determined by radiograph. Sicuranza et al²⁸ also corrected the full amount of the inequality, but assessed LLI using the position of the iliac crests. Friberg¹⁴ used lifts that were a few millimeters less than LLI measured by radiograph. Defrin et al¹¹ used lifts equal to LLI minus 10%. Lift studies, therefore, have not provided clinicians with sufficient guidance for selecting the amount of correction needed when utilizing lift therapy. Lift studies also have utilized different strategies for adjustment of the lift height. Gofton¹⁶ and Sicuranza et al²⁸ provided lifts that fully corrected the subjects' LLI, while Friberg¹⁴ and Defrin et al¹¹ gradually adjusted corrective lift height over time.

The purpose of this pilot study was to determine the effectiveness of a specific lift therapy procedure for subjects with chronic LBP who have an LLI. Subjects determined their own optimal lift height correction based on resolution of LBP symptoms. Prolift and postlift therapy changes in pain and disability were measured with questionnaires. We also examined the absolute difference between clinical assessment and radiography methods for determining LLI.

METHODS

Subjects

SUBJECTS WHO COMPLETED THIS study included 12 volunteers over the age of 18 who reported having chronic LBP and demonstrated an LLI. LBP was defined as pain or stiffness between the costal margins and gluteal folds.³¹ LBP was considered chronic if symptoms had been present for at least 3 months.³¹ The minimum LLI required for subject inclusion was 6.4 mm (0.25 in), as measured by the radiographic technique. Friberg¹⁴ reported that an LLI greater than 5 mm could cause LBP. Subjects also had to be able to walk a minimum of 30 m without the use of an assistive device and to read and speak English.

Subjects were excluded from the study if they had used any of the following during the 3 months prior to enrollment in the study: heel lifts, shoe lifts, or foot orthotics that had heel lift correction for LLI. Subjects were excluded if they reported any history of (1) sciatica, (2) lumbar disc herniation, (3) spondylolysis or spondylolisthesis, (4) traumatic back injury, (5) back surgery, (6) compression fracture, (7) rheumatoid arthritis, (8) ankylosing spondylitis, or (9) any musculoskeletal or neurological condition(s) other than LBP that limited their ability to walk normally. Individuals with disc herniation were not included because of concern that lift intervention might exacerbate their LBP symptoms.

Radiation exposure secondary to radiographs required special considerations for subject selection. Females were excluded if they were pregnant or planned on becoming pregnant during the study period. Males were excluded if they were planning on fathering a child within the next 6 months. Subjects who had participated in a radiation study within the past year were excluded. Any university or medical school employee who was exposed to radiation during their work was also excluded from the study.

Subjects agreed not to use any pain medications for their LBP during the 4

days prior to enrollment in the study and throughout the duration of the study. Any subject who was regularly taking antidepressant or anticonvulsant medication that had an analgesic effect was allowed to enroll in the study. The subject agreed to continue to take the medication at the same dosage during enrollment of the study unless otherwise instructed by his or her physician. Subjects also agreed to not receive any other form of treatment (eg, physical therapy, massage therapy, or chiropractic treatment) while enrolled in the study. Any subject who was currently receiving treatment for LBP was asked to cease treatment for at least 2 weeks prior to enrolling in the study. Subjects who had initiated any exercise program as a result of therapy intervention during the month prior to study enrollment had to have discontinued that exercise program at least 2 weeks prior to enrollment. Subjects were asked to avoid any changes in their current level of activity and exercise during their enrollment in the study in terms of time, duration, and intensity. Subjects signed a statement of informed consent prior to participating in the study. The study protocol was approved both by the Biomedical Internal Review Board and by the Radiation Safety Committee at The University of North Carolina at Chapel Hill.

Procedures

A telephone questionnaire was administered to potential subjects to determine their eligibility for participation in the study. Individuals who appeared to meet the inclusion criteria were further screened by 1 of 2 investigators at a convenient location. Each of the investigators had approximately 4 years of clinical experience in orthopaedic physical therapy practice. Subjects completed a consent form prior to the screening examination. This screening examination included a physical examination for LLI and completion of a disability questionnaire and 2 visual analog scale (VAS) ratings for general LBP and LBP experienced during standing. The subjects used a VAS

(range, 0-100 mm) to rate their average LBP during the past week and their LBP when standing for at least 5 minutes during the past week. The descriptors at the ends of the VAS rating scales were “no pain” and “pain as bad as you can imagine.” A metric ruler was used to measure to the nearest millimeter the VAS ratings for LBP. The disability questionnaire was used to determine the effect of each subject’s LBP on daily function. The disability questionnaire was modeled from Version 2.0 of the Oswestry Disability Index, with permission.¹³ The Oswestry Disability Index has been demonstrated as a reliable, valid, and responsive outcome measure for patients with LBP.¹³ Two modifications were made to Version 2.0 of the Oswestry Disability Index: subjects were asked to report the average pain experienced “during the past week” instead of the pain experienced on the day the questionnaire was completed, and the wording “at this moment” was changed to “during the past week” for all relevant response categories. These 2 modifications were made based on our clinical experience that patients with LBP and an LLI typically report intermittent LBP that varies daily and with different activities. Subjects may not have had pain at the time the disability questionnaire was administered. We considered 1 week as an adequate time for subjects to reflect upon the variation in symptom severity.

The disability questionnaire consisted of 10 questions that closely reflected the difficulties encountered by persons with LBP during daily activities (eg, sitting, standing, walking, or sleeping). Each question had 6 possible answers and each possible answer depicted a different level of difficulty for the activity. Each question was scored from 0 to 5 points, with a greater score indicating more disability. A total raw score was derived by summing the scores of all questions. The total raw score was then multiplied by 2 to arrive at a percentage score, with a score of 0% indicating no disability and a score of 100% indicating maximum disability.

Subjects were also asked to indicate

any prior treatment for their LBP (eg, medication, physical therapy, chiropractic, or lifts). LLI was assessed clinically using an indirect method. Standard masonite boards 3.18 mm (0.125 in) thick were placed under the suspected shorter limb during clinical assessment to screen potential participants for LLI. The tester palpated the greater trochanters and as many pelvic landmarks as possible (ie, iliac crests, anterior superior iliac spines, posterior superior iliac spines, and ischial tuberosities) to determine the existence of an LLI.⁶ If an LLI was suggested by the asymmetry of at least 2 sets of landmarks (eg, greater trochanters and iliac crests), the masonite boards were placed under the foot of the suspected shorter limb until the examiner determined that the greater trochanters and other pelvic landmarks were level. Subjects with a suspected LLI equal to or greater than 6.4 mm (0.25 in), based on the indirect assessment method, were then scheduled for a radiograph to be performed on a separate day.

Radiographs

Radiographs were acquired at the Division of Radiologic Science Laboratory at the University of North Carolina at Chapel Hill. Radiographs were used to determine the magnitude of the LLI and not for any diagnostic purposes. The radiographic images were produced using a Fischer Micro X-650 generator (Fischer X-Ray Corporation, Denver, CO) and an 800-speed screen/film receptor. The X-ray tube potential for image acquisition was set at a 125-kV peak. An 8:1/80 line antiscatter grid was used to improve the image contrast. The subject’s entrance skin exposure level was reduced to minimal levels by placing a compound filter in the path of the beam just in front of the X-ray tube. The exposure factors were adjusted according to each subject’s size to produce an optimal density of approximately 1.2. The image quality was adequate for clear identification of anatomic landmarks needed for all measurements.

Female subjects were scheduled for radiographs within the first 10 days of their menstrual cycle as an additional precaution to avoid the possibility of testing a pregnant subject. Subjects wore plain T-shirts and shorts for testing. Subjects also wore the shoes and any inserts or orthotics they most commonly wore during the radiograph acquisition. Shoe wear and orthotics have the potential to influence foot posture and, consequently, functional limb length.⁶ The radiograph procedure for measuring LLI was modeled after procedures used by Brady et al.⁶

A carpenter’s level was used to determine the levelness of the floor on which subjects stood during acquisition of the radiographs. Subjects were asked to stand with equal weight bearing on each limb, and with their knees fully extended, but not hyperextended. A standard set of sliding calipers was used to insure that the distance between the estimated centers of the ankle joints was equal to the distance between the subject’s 2 anterior superior iliac spines. The radiographer qualitatively assessed the subject’s position and assisted the subject with any necessary repositioning. A shadow shield was used at the source of the X-ray beam to minimize exposure to male gonadal tissue. A shield was not used for female subjects because the placement of a shield to minimize exposure to the female gonadal tissue would have resulted in failure to image the femoral heads adequately. The center of the X-ray beam had to be within 20 mm of the level of the most superior aspect of the more superior femoral head for an acceptable radiograph. The investigators selected this beam location criterion to minimize measurement error related to distortion of images from X-ray beam dispersion. If needed, a second radiograph was acquired to meet this requirement using the same positioning procedures previously described. A final radiograph was acquired to analyze the test-retest reliability of the radiographic procedure. The subject walked away from the positioning area prior to being repositioned for acquisition of the final radiograph.

An investigator measured the difference in heights between the most superior aspects of the 2 femoral heads to the nearest millimeter using a metric ruler for all radiographs the day the radiographs were acquired. The measured difference between each femoral head was multiplied by a conversion factor of 0.80 because of magnification associated with the radiographic procedure. Two blinded investigators measured all radiographs to the nearest millimeter again on a later date. The radiographic method was highly reliable (intrarater reliability, $ICC_{3,1} = 0.98$; interrater reliability, $ICC_{3,1} = 0.99$; test-retest reliability, $ICC_{3,1} = 0.99$). The 95% confidence intervals for the absolute differences between paired observations were 0.01 to 0.47 mm for intrarater reliability, 0.18 to 0.86 mm for interrater reliability, and 0.32 to 1.28 mm for test-retest reliability.

Lift Therapy

Following the radiograph procedures, subjects provided preintervention measurements on the disability questionnaire and the 2 VAS ratings for LBP so that the investigators could determine how stable their LBP symptoms and function were prior to the intervention. Lift therapy was the only intervention that subjects received. Subjects began lift therapy during this visit. Heel lifts and inserts used inside subjects' shoes were constructed from sheets of NickelPlast (Alimed, Inc, Dedham, MA). A grinder was used to smooth and bevel the edges of the heel lift inserts. A local shoe repair shop constructed the external shoe lifts from crepe sheets (JH Cook and Sons, Granite Quarry, NC). Subjects were required to wear the lift in their shoes when they were walking or standing while enrolled in the study. The magnitude of each subject's initial lift correction was 3.18 mm (0.125 in). Initial lifts were placed inside the subject's shoe. Investigators attempted to place full-length inserts inside the shoe. Heel lifts were utilized in cases when the shoe design did not allow enough space in the toe box for a full-length insert. In most

cases, heel lifts were utilized because of the subject's shoe design. Lift height was increased in 3.18-mm (0.125-in) increments every 7 to 10 days. Several authors have recommended increments of 3.2 to 6.4 mm every 1 to 2 weeks.^{5,6} The overall height of the full-length insert and/or heel lift did not exceed 9.54 mm (0.375 in) inside the shoe. A full-length lift was added to the plantar surface of the shoe of the shorter limb for subjects who required a lift greater than 9.54 mm (0.375 in).

Subjects were asked to complete a daily log to document the number of hours the lift was worn each day, the amount of lift used, the type of shoes worn, general symptoms experienced, and the activities that the subject performed. The log also acted as a reminder for subjects to increase their lift height every 7 to 10 days. The investigators maintained weekly telephone or electronic mail contact to remind subjects to increase their lift height or to determine if subjects had reached optimal lift height. Each subject decided the optimum lift height based on symptoms. Subjects were instructed to maintain their current lift height if symptoms completely resolved, even if the amount of lift correction was less than the magnitude of their LLI. Subjects were not allowed to use a magnitude of lift correction that exceeded the magnitude of their LLI. Any subject who reported increased symptoms for more than 2 days following an increase in corrective lift was instructed to contact 1 of the investigators. Investigators made any necessary adjustments (decreasing or maintaining current lift height) based on each subject's symptoms. If the investigators elected to maintain the current lift height, the subject was followed daily by telephone contact. Subjects who continued to report an increase in symptoms were instructed to return to the previous lift height that had been used.

Postintervention Measurements

Each subject reported to the test site 7 to 10 days after reaching his or her optimal lift height to provide postintervention

measurements. The mean (SD) number of days between prelift and postlift testing was 28 (13.3) days. Subjects completed the disability questionnaire and the 2 VAS ratings for LBP during this testing session.

1-Month Follow-up Testing

Subjects also completed a 1-month follow-up disability questionnaire and VAS ratings for LBP an average (SD) of 38 (7.5) days after the first set of postintervention measurements.

Data Analysis

Descriptive statistics were generated for subjects' age, mass, height, body mass index (BMI), years since onset of symptoms, magnitude of LLI, percentage of lift correction ($[\text{amount of lift correction/magnitude of LLI}] \times 100\%$), and completion of a daily log. Separate 1-way within-subject analyses of variance were used to assess the effectiveness of the corrective lift on the 2 VAS ratings for LBP and the disability questionnaire scores. Any necessary follow-up pairwise comparisons were conducted using a Tukey honestly significant difference analysis.

The minimally clinically important difference (MCID)²⁶ was calculated for each subject's VAS and disability questionnaire scores to determine whether the subject's pain and function had remained the same, improved, or gotten worse. An MCID of 20 mm³² was utilized for both the general and standing VAS pain ratings, and an MCID of 4%³ was utilized for the disability questionnaire. MCID contrasts were made between the 2 preintervention assessments, between the second preintervention assessment and the first postintervention assessment, and between the second preintervention assessment and the second postintervention assessment.

The absolute difference between the LLI measurements acquired by the indirect method (palpation of pelvic landmarks and use of masonite boards) and the radiographic method was determined

for each subject to represent error associated with the indirect method. Data for this comparison were available from 24 individuals who had been screened for participation in the study. One of the investigators had performed the indirect method for LLI assessment on 10 subjects, and the second investigator performed the indirect method for LLI assessment on the remaining 14 subjects. The average absolute difference between the indirect method and the radiographic method for LLI assessment was calculated for each of the 2 investigators. A *t* test was performed to determine if the measurement error associated with the clinical determination of LLI was significantly different between the 2 investigators. A Pearson product moment coefficient of correlation was performed to determine the relationship between the BMI of our subjects and the absolute difference between the indirect clinical measurement method and the radiographic method for determining LLI. This analysis was conducted to determine if body composition was related to error in making the indirect determination of LLI.

RESULTS

Subjects

A TOTAL OF 114 INDIVIDUALS FROM Chapel Hill, Durham, and Raleigh, NC responded to advertisements for the study. Seventy-five respondents were excluded after telephone screening because they did not meet inclusion and exclusion criteria, they were unable to travel to testing sites, or they were not interested in committing to the study. Thirty-nine respondents were physically screened by the investigators at a place of convenience. Thirteen individuals were excluded because they did not have an LLI when measured using the indirect clinical method. Twenty-six subjects (11 males and 15 females) were recruited for this study. Two female subjects did not report for the radiograph sessions for unknown reasons and did not return our telephone calls. Twenty-four subjects reported for the radiograph sessions, and 15 subjects (8 males and 7 females) met the requirements of having an LLI equal to or greater than 6.4 mm (0.25 in), based on the radiographic assessments. Three of these 15 subjects (2 males and 1 female)

did not complete the study protocol and were also excluded from the study. Two of these 3 subjects did not return phone calls after the baseline session and corrective lift fitting, and the other subject did not return the 1-month follow-up disability questionnaire and VAS ratings for LBP. Twelve subjects (6 males and 6 females), therefore, completed the study protocol.

The mean (SD) age for subjects was 37.0 (14.9) years (TABLE 1), duration of low back symptoms was 10.8 (8.8) years, and LLI was 12.8 (5.1) mm. The mean percentage of lift correction was 61.3 % (SD, 23.8%; range, 33%-100%) of the LLI magnitude that was determined by measurements from the radiographs. Subjects in our study had received multiple treatments from healthcare practitioners prior to enrolling in our study. Ten subjects (83%) had used over-the-counter pain medications, and 4 subjects (33%) had taken prescription medications. Six subjects (50%) had sought chiropractic care, while 5 subjects (42%) had received physical therapy. No attempt was made to determine the specific interventions used by chiropractors or physical therapists.

TABLE 1		CHARACTERISTICS OF SUBJECTS (N = 12)								
Subject	Gender	Age (y)	Onset (y)	Height (m)	Mass (kg)	BMI (kg/m ²)	LLI (mm)	Lift Height (mm)*	Lift Correction (%)†	
1	F	44	15	1.66	80.0	29.0	9.6	6.4	67	
2	M	23	7	1.85	67.7	19.8	9.6	9.5	99	
3	F	21	7	1.82	75.9	22.9	9.6	3.2	33	
4	F	27	10	1.62	55.0	21.0	6.4	6.4	100	
5	M	54	30	1.75	121.8	39.8	19.2	15.9	83	
6	M	40	10	1.92	81.4	22.1	19.2	9.5	49	
7	M	27	5	1.85	97.7	28.5	12.8	9.5	74	
8	M	36	10	1.85	111.8	32.7	22.4	9.5	42	
9	M	32	4	1.91	96.8	26.5	8.0	3.2	40	
10	F	19	5	1.68	55.0	19.5	9.6	3.2	33	
11	F	62	1	1.64	57.7	21.5	12.0	6.4	53	
12	F	59	26	1.70	85.7	29.7	15.2	9.5	63	
Mean		37.0	10.8	1.8	82.2	26.1	12.8	7.7	61.3	
SD		14.9	8.8	0.1	21.8	6.1	5.1	3.7	23.8	

Abbreviations: BMI, body mass index; onset, years since the onset of low back pain symptoms; LLI, limb length inequality.
 * Final corrective lift chosen by subjects during the intervention.
 † (Lift height/LLI) × 100%.

TABLE 2

DESCRIPTIVE STATISTICS FOR GENERAL PAIN RATINGS (N = 12), STANDING PAIN RATINGS (N = 10), AND DISABILITY QUESTIONNAIRE SCORES (N = 12)*

	Screening	Preintervention	Postintervention	1-mo Follow-up
General pain rating (mm)	42.3 ± 20.2	49.7 ± 16.0	21.4 ± 15.8	18.5 ± 14.2
Standing pain rating (mm)	43.1 ± 26.0	42.5 ± 16.3	15.8 ± 12.0	16.6 ± 12.8
Disability Questionnaire score (%)	18.0 ± 7.2	18.8 ± 6.9	10.2 ± 5.0	10.0 ± 5.7

* Values are mean ± 1SD. The screening and preintervention measurements are significantly greater than the postintervention and 1-month follow-up measurements for the general pain ratings ($P = .006$), the standing pain ratings ($P = .002$), and the disability questionnaire ($P = .001$). Pain rating was based on a 100-mm visual analog scale, with 0 being “no pain” and 100 being “pain as bad as you can imagine.” Disability was assessed with a modified version of the Oswestry Disability Questionnaire, with 0 representing no disability and 100 maximum disability.

Nine of the 12 subjects (75%) completed their daily log and reported compliance in wearing their lifts on a regular basis while enrolled in the study. The 3 subjects who did not complete or return their daily log verbally reported compliance in wearing their lift on a regular basis. A follow-up question after data collection, for which 7 of 12 subjects responded, indicated that subjects spent an average of 61% of their waking hours sitting and 39% standing or walking while enrolled in the study.

Indirect Method Versus Radiographic Method for Determining LLI

Radiographs were acquired for 24 subjects. The mean absolute difference between the indirect clinical assessment of LLI and the radiographic assessment

of LLI was 4.5 mm (SD, 3.0 mm; range, 0.1-10.3 mm) and 5.0 mm (SD, 4.6 mm; range, 0.0-13.5 mm), respectively, for the 2 investigators who conducted the clinical assessments of LLI. The t test analysis indicated no significant difference between the 2 investigators for the error associated with making the clinical assessment of LLI ($t = 0.35, P > .73$). We elected, therefore, to combine data for the 2 investigators to determine an average absolute difference between the indirect clinical assessment of LLI and the radiographic determination of LLI. The mean absolute difference between these 2 assessments of LLI was 4.7 mm (SD, 3.7 mm; range, 0.0-13.5 mm) for the 2 investigators. The correlation between BMI and the clinical measurement error was $r = 0.74$.

Pain and Disability Measures

LBP ratings and disability questionnaire scores were acquired at each assessment. The VAS rating for standing pain was added to our procedures after the first 2 subjects had already enrolled in the study. Standing LBP ratings, therefore, were only collected for 10 of the 12 subjects at each assessment. Descriptive statistics for the 2 VAS ratings of LBP and the disability questionnaire appear in **TABLE 2**. The 1-way within-subjects analysis of variance indicated significant differences among the screening, preintervention, postintervention, and 1-month follow-up measurements for general pain ratings ($F_{3,33} = 13.8, P < .0001$), standing pain ratings ($F_{3,27} = 12.6, P < .0001$), and disability questionnaire scores ($F_{3,33} = 18.5, P < .0001$). Tukey honestly significant difference analyses indicated that the postintervention and 1-month follow-up measurements were significantly less than the screening and preintervention measurements for general pain ($P = .006$), standing pain ($P = .002$), and the disability questionnaire ($P = .001$).

The LBP ratings for each subject at each time of measurement are represented in **FIGURE 1** for general pain and in **FIGURE 2** for standing pain. The disability questionnaire data across the times of measurement appear in **FIGURE 3** for each subject. All contrasts for MCID

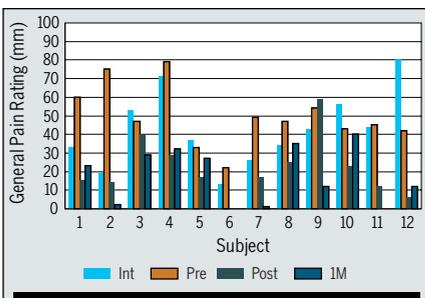


FIGURE 1. Individual scores for visual analog ratings of pain (0-100 pain scale) related to general pain for subjects at the screening visit (Int), just prior to lift intervention (Pre), 1 week following the completion of the intervention (Post), and at 1-month follow-up (1M). Subject 6 had a pain rating of 0 at 1 week following the completion of the intervention and at 1-month follow-up. Subject 11 had a pain rating of 0 at 1-month follow-up.

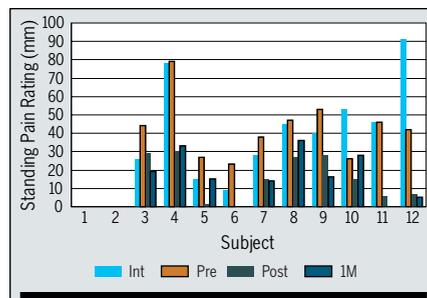


FIGURE 2. Individual scores for visual analog ratings of pain (0-100 pain scale) related to standing for subjects at the screening visit (Int), just prior to lift intervention (Pre), 1 week following the completion of the intervention (Post), and at 1-month follow-up (1M). Subject 6 had a pain rating of 0 at 1 week following the completion of the intervention and at 1-month follow-up. Subject 11 had a pain rating of 0 at 1-month follow-up. Ratings were not available for subjects 1 and 2.

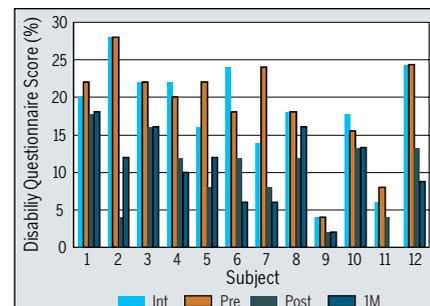


FIGURE 3. Individual scores for the disability questionnaire (range, 0%-100%, with higher score indicating greater disability) for subjects at the screening visit (Int), just prior to lift intervention (Pre), 1 week following the completion of the intervention (Post), and at 1-month follow-up (1M). Subject 11 had a disability questionnaire rating of 0% at the 1-month follow-up assessment.

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in the 2 pain ratings and the disability questionnaire appear in **TABLE 3**. Most subjects demonstrated no change in any of the 3 outcome measures between the screening measurements and the pre-intervention assessments. One of the 12 subjects demonstrated a decrease in general pain rating, 2 of 10 demonstrated a decrease in standing pain rating, and 1 of 12 demonstrated a decrease in disability questionnaire score between the 2 preintervention times of measurement. No subject demonstrated a clinically significant increase in pain or in disability questionnaire scores between the preintervention assessment and the postintervention assessment. A majority of the subjects demonstrated improvement in the outcome measures between these 2 times of measurement, while approximately a third or less of the subjects demonstrated no change in the measures. Similar results were observed for the comparison of the preintervention measures and the 1-month follow-up assessments.

DISCUSSION

OUR SUBJECTS REPORTED HAVING low back symptoms for a mean (SD) of 10.8 (8.8) years, suggesting that their condition was chronic in nature. The screening and preintervention measurements indicated that our subjects' pain and function were stable for a period of greater than 2 weeks (mean \pm SD, 16 \pm 7 days) prior to lift intervention, suggesting that any changes in pain and function might be attributable to lift intervention rather than other factors.

The MCID analyses of the VAS pain ratings indicate that a majority of our subjects had a clinically significant decrease in their general pain symptoms (9 of 12 subjects) and pain associated with standing (7 of 10 subjects), based on their preintervention and postintervention VAS pain ratings. These results are in agreement with previous lift intervention studies for which investigators reported significant relief of LBP

after lift therapy for individuals with LLL.^{14-16,28} The results for the disability questionnaire suggest that a majority of our subjects (9 of 12) had a clinically significant improvement in their function following corrective lift intervention. Readers should use caution, however, in interpreting these results because the disability questionnaire used in our study was a modified version of the Oswestry Disability Index (Version 2.0).

The reduction in general pain and pain experienced with standing, and improvement in function were noted approximately 1 week following establishment of final lift intervention height. Subjects continued to report pain values and disability questionnaire ratings at the 1-month follow-up that were similar to the values they reported 1 week following their final lift adjustments. Subjects in our study reported at the time of enrollment that they had previously received multiple treatments of varying effectiveness, including over-the-counter medications, prescription medications, chiropractic care, and physical therapy. The lift therapy used in our study had positive results for most subjects and was implemented at relatively little cost.

Previous lift studies^{23,28} have demonstrated prompt relief of back pain, with significant relief of symptoms after 2 days and through assessments at 1 month following lift intervention. Other investigators have reported long-term significant improvements after lift therapy. Friberg¹⁴ followed subjects a mean of 1.5 years (range, 0.5-15 years), Giles and Taylor¹⁵ followed subjects up to 2 years, and Gofton¹⁶ followed subjects 3 to 11 years following lift intervention. All of these investigators reported significant long-term improvements relative to relief of low back symptoms.

Previous authors^{5,10} have different opinions regarding the amount of corrective lift that should be used initially, as well as the magnitude of additional lift material and the schedule for adding lift material. The magnitude of each subject's initial lift correction was 3.18 mm (0.125 in) in the present study, and was tolerated well by all subjects. Subjects in our study appeared to accommodate well to a gradual increase in lift height in multiple increments, completing their lift correction within an average (SD) of 28 (13.3) days. Two subjects, however, required additional time to accommodate to the

TABLE 3

PERCENTAGE OF SUBJECTS WHO DEMONSTRATED A MINIMALLY CLINICALLY IMPORTANT DECREASE, INCREASE, OR NO CHANGE IN THE OUTCOME MEASURES*

	First Preintervention Versus Second Preintervention	Second Preintervention Versus First Postintervention	Second Preintervention Versus Second Postintervention
General pain rating (n = 12)			
Decrease	8%	75%	67%
Same	67%	25%	33%
Increase	25%	0%	0%
Standing pain rating (n = 10)			
Decrease	20%	70%	70%
Same	80%	30%	30%
Increase	0%	0%	0%
Disability questionnaire (n = 12)			
Decrease	8%	75%	75%
Same	75%	25%	25%
Increase	17%	0%	0%

* Minimally clinically important differences in scores were 20 mm²² for the general and standing pain ratings and 4%³ for the disability questionnaire.

increase in lift height. These 2 subjects demonstrated a structural scoliosis in addition to their LLI. Clinicians, therefore, should closely monitor patients when lift therapy is used as an intervention in the treatment of LBP and other musculoskeletal problems are present, especially a structural scoliosis.

Three subjects met the criteria for adding lift material to the sole surface of the bottom of the shoe for the shorter limb. Only 1 subject, however, opted to add the lift to the exterior of the shoe. The other 2 subjects decided to maintain their lift height at 9.54 mm (0.375 in), despite having LLI of 15.90 mm (0.625 in) and 22.26 mm (0.875 in), respectively. The 2 subjects were allowed to stay at their current lift height. Both subjects noted they were hesitant to modify their shoes because of the expensive nature of their shoes. The possible negative cosmetic effect of an external shoe lift may have also influenced their decision not to add the shoe lift and, therefore, altered some of the study outcome measurements.³⁰

Radiographic methods are the gold standard for measuring LLI, as compared to clinical methods.⁶ Twenty-four subjects appeared to have an LLI of at least 6.4 mm (0.25 in), based on the clinical assessment of LLI. Only 15 (63%) subjects, however, demonstrated an LLI of at least 6.4 mm, based on radiographic assessment. The mean absolute difference of 4.7 mm (SD, 3.7 mm; range, 0.0-13.5 mm) between the indirect clinical measurement method and the radiographic method also indicates that measurement error is associated with this clinical method. Clinicians, therefore, should be cautious when determining interventions based on a clinically determined LLI of 5 mm or less.⁶ Clinicians, however, should not rule out the possibility of an LLI in the absence of an LLI on clinical examination, especially if patients present with LBP associated with standing and reduced with sitting. Subjects in our study also did not report any significant limitation in walking. A review of responses to

the question in the disability questionnaire specific to walking indicated that all subjects were able to walk at least 1.6 km. The measurement error associated with clinical assessments of LLI also may add further support for increasing the lift height based on patient's responses to lift intervention. A gradual increase in lift height may compensate for measurement error associated with the clinical assessment of LLI and reduce the chances of an increase in LBP symptoms in the event that too much corrective lift has been provided.

Obesity has been cited as one possible source of measurement error when using the indirect clinical method to determine the possibility of an LLI.⁸ The mean BMI of our subjects was 26.0, indicating that our population could be considered overweight ($>25 \text{ kg/m}^2$).² The correlation between BMI and error in making the clinical measurement of LLI was $r = 0.74$. Correlations ranging from 0.50 to 0.75 have been suggested as indicating a moderate to good relationship.²⁵ The relationship between BMI and clinical measurement error indicates that caution should be exercised when using the indirect method of LLI assessment for patients who are obese.

Previous authors have suggested either correcting the full amount of the LLI or a large portion of the full amount (eg, 90%), but these recommendations have been based more on anecdotal clinical successes rather than objective data.^{11,14,15,28} Subjects in our study, on average, chose a lift correction amount that represented 61.3% (SD, 23.8%) of their LLI based on radiographic analysis to reduce their LBP symptoms. Based on these preliminary results, we recommend that the total amount of the LLI should not be corrected, and that patients should determine the lift height based on their response to gradual lift intervention.

Limitations of this study include small sample size, lack of control group, and lack of blinding. Error in the clinical assessment of LLI at the time of screening

may also have resulted in some subjects not being enrolled in the study who would have otherwise qualified for the study following radiographic assessment of LLI. The results of this study, therefore, should be regarded as preliminary evidence for the effectiveness of lift intervention in patients who have chronic LBP and an LLI. Readers should note that approximately a third of our subjects demonstrated no change in LBP ratings following the intervention (TABLE 3), and a fourth of our subjects demonstrated no change in their disability questionnaire scores. Our design also did not control for placebo or Hawthorne effects. Subjects were informed upon enrollment, however, that the addition of corrective lift might exacerbate their LBP or produce other types of pain, and that these symptoms would indicate the need to contact the research team. As such, improvement in symptoms for the participants was not the only option known to them in advance of the intervention. Future studies should focus on randomized controlled trials that may provide stronger evidence for the positive effects of lift intervention observed in our study. These trials should compare the results of lift intervention to other interventions (eg, home exercise program, back school, etc). Additional research is also needed to examine lift intervention as a treatment option for other musculoskeletal disorders that may be associated with LLI, such as hip or knee joint dysfunction.

CONCLUSION

SHOE LIFTS MAY REDUCE LBP AND improve function for individuals who have chronic LBP and an LLI. Clinicians should consider selecting the amount of corrective lift height based on the patient's response to gradual increases in corrective lift, rather than correcting a fixed percentage of the LLI. Future studies involving a control group may help provide further evidence supporting the use of lift therapy in patients who have LBP and an LLI. ●

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