Kinematic Effects of Heel Lift Use to Correct Lower Limb Length Differences*

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The effect of the heel lift to correct a limb length difference was studied by electrogoniometry (elgons) in four male subjects with a limb length inequality between ¾ inch (0.48 cm) and ¾ inch (0.95 cm). Six elgons were attached to bilateral hip, knee, and ankle joints as the subject walked (3 mph) and jogged (6 mph) on the treadmill twice, once with the heel lift and once without. Recordings from the elgons examined maximal flexion and extension during support and swing phase, amplitude of movement (ROM), duration of each movement, and angular velocity of each joint. Within the limitations of the study, the following conclusions were drawn: 1) the addition of a heel lift did not appear to significantly affect biomechanical measures of gait; and 2) insertion of a heel lift did tend to cause more symmetrical movement for the maximum angle of hip extension and ROM of the swing plantarflexion phase of the ankle but more asymmetrical ROM of the swing flexion phase of the knee.

Research has shown that a lower limb length difference (LLD) may be present in 25-93% (depending on the source) of the population.8 A LLD that may be considered minor (1/4-1/2 inch, 1-2 cm) and not cause any problems in a nonathlete or sedentary individual, may become a major problem in the active athlete. The constant, repetitive strides made while training for a distance event may be predisposing to several injuries. Symptoms that have been suggested to be caused by LLD include sciatica as well as pain in the hip, knee, ankle, and iliotibial band.3,7,9,10,12,13

The treatment for the alleviation of LLD is the insertion of a heel lift equal to the height of the discrepancy and inserted into the shoe of the short leg in order to equalize the lengths of the lower extremity.6,12 Several authors have supported the theory suggesting that the use of the heel lift ensures biomechanical symmetry of movement which is essential to decrease the chance of injury to an active individual.3,7,10,13

Other writers have reached conclusions contrary to the authors previously reviewed. Hult,5 in an investigation of Swedish industrial and factory workers, found no differences in the incidence of LLD in workers complaining of lumbar spine trouble and the entire study population. Fisk and Biagent4 state that “moderate degrees of leg length discrepancy played little if any part in the etiology of back ache.” Gross,9 in reviewing young adults’ perceptions on the functional effects of LLD, found that individuals with less than an inch (2 cm) difference did not consider the discrepancy to be a problem. However, neither investigator studied athletes as a separate group.

Only one investigation analyzed the changes that occur with the insertion of a heel lift.2 Investigators hypothesized that the insertion of a heel lift had a positive effect on the running gait; however, two problems arise. First, the study investigated the kinetic energy changes occurring in the lower extremity but did not define the actual changes in displacement occurring at the joints of the body. Second, the study dealt with a LLD of over 1 inch (2.5 cm) which is very large clinically.14

It is suggested from the literature that minor deviations from a normal running gait due to LLD may severely handicap the athlete’s ability to per-
form and be predisposing to further injury. However, there is little biomechanical evidence as to what these deviations are, what specific changes occur with the addition of a heel lift, and if the addition of the heel lift is indeed advantageous to efficient locomotion.

The purpose of this study was to investigate bilateral changes in range of motion, duration, and angular velocity of the hip, knee, and ankle during the swing and support phase when a heel lift, which is inserted into the shoe of the short limb in order to correct a LLD in an effort to produce symmetrical movements, is removed. Potential changes in gait patterns were examined while walking (3 mph) and jogging (6 mph) on the treadmill.

**METHODS**

**Subjects**

Four male volunteers having a LLD between \(\frac{3}{16}\) inch (0.48 cm) and \(\frac{3}{4}\) inch (0.95 cm) served as subjects for this study. All subjects had worn a heel lift for more than 1 year and for the purposes of this study were defined as “experienced” heel lift users. Descriptive data are presented in Table 1.

The criteria for LLD used in this study are that the subjects present with the following characteristics on the short limb side: 1) low anterior superior iliac spine, 2) low posterior superior iliac spine, and 3) low iliac crest. A LLD between \(\frac{3}{16}\) and \(\frac{3}{4}\) inch was chosen because this difference is large enough to cause lower extremity asymmetry that can be accurately measured, but not so large that a correction beyond a heel lift is necessary. Subotnick suggested that forefoot control is necessary with an orthotic device to correct a difference greater than \(\frac{1}{2}\) inch (1.3 cm), and a heel lift alone does not supply enough foot control. In order to measure LLD, each subject was asked to stand erect with his bare feet facing forward, shoulder width apart, knees held in full extension, and hindfoot in the neutral position. The LLDs of the subject were measured with a Pelvic Level (J. A. Preston Corp., 60 Page Rd., Clifton, NJ 07012). The Pelvic Level was positioned on the superior aspect of the subject’s iliac crest with the bubble in the leveling device showing tilt in the subjects with a LLD. Calibrated blocks were placed beneath the heel of the short side until the crests were level, as indicated by the bubble on the leveling device moving to the center. The width of the blocks needed to level the crests was considered the amount of LLD the subject possessed. The subject was then given a heel lift of Pelite (Alimed Co., 68–70 Harrison Ave., Boston, MA 02111) material structured to equalize the LLD and placed in the shoe of the short limb.

**Equipment**

Six electrogoniometers (elgons) were attached to the subject at bilateral hip, knee, and ankle joints. An elgon is an instrument which uses electrical circuitry and recording devices to make a continuous record of joint movement. Several types of elgons have been designed for use with the different joints. The one used in this investigation is similar to the universal elgon described by Adrian et al. A Wheatstone Bridge was used to balance the circuits and calibrate the output. Data were recorded by a model 1600 Strip Chart Recorder manufactured by the MFE Corp.

**PROCEDURES**

**Data Collection**

Subjects reported to the testing area wearing shorts and rubber soled running shoes. All subjects had previous experience with the treadmill.

**TABLE 1**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age</th>
<th>Weight</th>
<th>Height</th>
<th>LLD</th>
<th>Leg</th>
<th>Time of heel lift use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>23</td>
<td>145 lb</td>
<td>5'9&quot;</td>
<td>(\frac{3}{16}) inch</td>
<td>Right</td>
<td>13 months</td>
</tr>
<tr>
<td>2</td>
<td>28</td>
<td>165 lb</td>
<td>5'9&quot;</td>
<td>(\frac{3}{8}) inch</td>
<td>Left</td>
<td>36 months</td>
</tr>
<tr>
<td>3</td>
<td>26</td>
<td>74.8 kg</td>
<td>5'11&quot;</td>
<td>(\frac{1}{4}) inch</td>
<td>Right</td>
<td>18 months</td>
</tr>
<tr>
<td>4</td>
<td>28</td>
<td>72.6 kg</td>
<td>6'0&quot;</td>
<td>(\frac{1}{4}) inch</td>
<td>Right</td>
<td>29 months</td>
</tr>
</tbody>
</table>
Data Analysis

From the elgon recordings (Fig. 2), information was obtained from each joint. Measurements included maximal flexion and extension (mean angles) during support phase and swing phase of the knee and ankle. Maximal flexion is the joint angle at the termination of flexion and beginning of extension; maximal extension is the converse. The swing phase is the position of the stride during which foot swings free of support. The support phase is when the foot is on the surface and begins with heel strike and ends with push off. Maximal flexion and extension of the hip was also examined.

In addition, the amplitude of movement (or total range of motion) which is the difference between maximum flexion and maximum extension was measured. The following movements were examined for the knee and ankle: 1) swing extension, 2) support flexion, 3) support extension, and 4) swing flexion. Only the total amplitude of movement for flexion and extension were examined for the hip.

Also, the duration of each movement, which is time required to move from one maximum angle to the other, was computed for the hip, knee, and ankle from the horizontal travel speed of the recording paper. Angular velocity was also computed. This computation gave an average value for complete movement since no allowance is made for the positive and negative accelerations at the beginning and end of the movements.

Statistical analysis utilized the analysis of vari-
Fig. 3. Interaction effect of lift x limb for angle of maximum extension of the hip. All differences between the short limb and long limb were significant. However, differences for each limb with and without the lift were not significant.

ance (ANOVA) with repeated measures. The Tukey HSD Test was used for post hoc analysis. Significance was accepted at $p < 0.05$.

RESULTS

No significant differences were found due exclusively to the use of the heel lift for any dependent variables. However, there were interactions which were found to be significant. The interaction between heel lift (with and without) and limb (short and long) was significant for the angle of maximum hip extension ($F = 25.31, p < 0.01$), the range of motion of the swing plantarflexion phase of the ankle ($F = 14.31, p < 0.03$), and the range of motion of the swing flexion phase of the knee ($F = 180.24, p < 0.001$). These interactions are graphed in Figures 3 through 5.

DISCUSSION

Although no significant differences were found due exclusively to the use of the heel lift for any of the measures in the study, significant interactions were found. These interactions indicated trends toward symmetry of movement with the insertion of the heel lift for the angle of maximum hip extension and the range of motion of the swing plantarflexion phase of the ankle. The interactions indicated a trend toward asymmetry of movement with the insertion of a heel lift upon range of motion of the swing flexion phase of the knee. No other measurements related to the experimental question investigating biomechanical changes due to the insertion of a heel lift to correct LLD were significant.

These results differ from the only other investigation on the kinematic changes in gait due to LLD by DeLacerda and Wickoff. The difference may be due to several reasons. The study by DeLacerda and Wickoff used only one female subject and based any conclusions from the investigation on that single subject. In addition, the
subject had a LLD of 3.18 cm (1.25 inches) while all the LLDs in the present study were less than 1 cm (½ inch). Last, DeLacerda and Wickoff measured kinematic changes at a walking speed (3 mph) while the present investigation also incorporated a faster speed (6 mph).

There are three limitations of the design of this study. The first is that the number of subjects is small. A greater number of subjects would be expected to reduce the variability and increase the probability of finding significant differences. This is especially significant in regard to the cases where post hoc tests did not support the significant F ratios for interaction. Second, even though all four subjects were young, active males with a LLD who had worn a heel lift for over 1 year, they differed in their activity level. Two of the subjects were actively engaged in a running program jogging 3–5 miles, 4–5 times a week. The other two subjects were active in sports such as biking, softball, and soccer and were not involved in a consistent jogging program. Further research utilizing a larger number of subjects and a more specific population (trained subjects) may lead to different results.

A third limitation of the present investigation was that all the measurements were taken in a sagittal plane of the lower extremity. No attempt was made to measure rotation of the long axis of the limb or movements in the transverse plane which occur during gait such as tibial rotation and pronation-supination of the foot. While very few significant differences were obtained in this study, further investigations incorporating the rotary components of movement may lead to interesting findings.

CONCLUSION

1) The addition of a heel lift to the short limb did not appear to significantly affect the biome-
chanical measures of maximal flexion and extension during support and swing phase, range of motion, duration of movement, and angular velocity of the hip, knee, and ankle while walking (3 mph) and jogging (6 mph) on the treadmill.

2) Insertion of a heel lift did tend to cause more symmetrical movement for the maximum angle of hip extension and range of motion of the swing plantarflexion phase of the ankle, but more asymmetrical range of motion of the swing flexion phase of the knee.

Implications

It would appear reasonable to employ a heel lift on a trial basis for the treatment of symptoms possibly related to LLD, but it is important to realize that all subjects do not respond to the use of a heel lift in the same way. Therefore, it is imperative that treatment with a heel lift be individualized to each subject and that frequent monitoring of the subject’s response is mandatory.

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REFERENCES

5. Gross RH: Leg length discrepancy, how much is too much? Orthopedics 1:307-310
HEEL LIFT FOR LOWER LIMB LENGTH DIFFERENCES