EFFECTS OF SHOE LIFTS ON GAIT PARAMETERS FOR UNILATERAL CDH PATIENTS

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Abstract: Shoe lifts are able to correct the leg-length discrepancies and relieve limp gaits of patients with unilateral congenital dislocation of the hip (CDH). Four unilateral CDH patients were treated for leg-length equalization using shoe lifts. We evaluated gait parameters and the performance of the shoe lifts. The results showed that shoe lifts not only improved pelvic levelness, but also reduced supinatory forces within the shorter limb and pronatory forces within the longer limb. However, shoe lifts added vertical ground-reaction force on the affected side which may cause increases of joint stress of the lower limbs. To diminish the reaction force, the heels and outsoles should be made of materials with proper shock-absorbing capabilities and as little mass as possible. Moreover, the forefoot rocker in the shoe lifts provided easier and smoother motion during the process of propelling the body forward, however, the rocker also reduced the support force for the contraction of the gastrocnemius and soleus muscles, and thus diminished the propelled force.

Introduction

Adult patients with unilateral congenital dislocation of the hip (CDH) have leg-length discrepancies. Leg-length discrepancies have been related to postural anomalies during standing and walking with a characteristic limp that causes more energy expenditure and asymmetrical gait [1]. The long-term effects of leg-length discrepancies are low-back pain and arthritis of the hip on both limbs [2].

Total hip arthroplasty (THA) is not appropriate for the young or adult CDH patients without severe arthritis on the hip. Lengthening of the shorter limb requires long and complicated processes [3]. To correct the leg-length discrepancies to a reasonable range and relieve the amount of complications, shoe lifts on the lower limbs have become acceptable and necessary for the unilateral CDH patients [4]. Shoe lifts improve the patients' ability to walk efficiently and comfortably which have been widely observed in clinical application, but a comprehensive gait analysis of unilateral CDH patients after wearing shoe lifts is still lacking. The objectives of this study were to investigate gait parameters with the use of shoe lifts for adult patients with unilateral CDH and to determine the performance of shoe lifts.

Subjects and Methods

Four unilateral CDH patients (one male and three female) who had leg-length discrepancy participated in this study. Two patients had legs shorter on the left side and two patients had legs shorter on the right (Table 1). Their ages ranged from 22 to 38 years (mean, 31 years), body weight ranged from 47 to 59 kg (mean, 50.8 kg), and body height ranged from 151 to 170 cm (mean, 159 cm). Leg-length discrepancies, measured as the difference between the highest point of the iliac crest and the lateral malleolus without force added to achieve pelvic levelness, ranged from 5.5 to 7.5 cm (mean, 6.4 cm). Among the four patients, two patients had used shoe lifts since childhood, while the others had never used shoe lifts.

Table 1: Subject characteristics

No.	Age	Sex	LLD (mm)	Affected side	Height (cm)	Weight (kg)
1	38	M	7.5	L	170	59
2	22	F	7	R	151	49
3	38	F	5.5	R	156	48
4	26	F	5.5	L	159	47

LLD: leg-length discrepancy

Fifteen light-reflecting markers were attached to each subject according to the Helen-Hays method [5]. These anatomical landmarks are as follows: the anterior superior iliac spine (ASIS), the greater trochanter, the mid-thigh, the knee joint line, the mid-shank, the lateral malleolus, and between the second and third metatarsal heads bilaterally and 10 cm above the sacrum at the midline (Figure 1). Each subject walked at his or her selected speed on an 11 m long and 2.1 m wide walkway equipped with a motion analysis system (ExpertVision, Motion Analysis Corporation, Santa Rosa, CA) containing six cameras and three force plates (Type 9281B, Kistler Instrument, Winterhur, Switzerland). A photocell trigger was placed 3 m away from the first force plate to synchronize the signals from the cameras and the force plates. Data from four walking trials were collected for each subject while with and without shoe lifts. Kinematics and kinetics data of both limbs were measured during each trial. Ortho Track software (Motion Analysis Corporation, Santa Rosa, CA) was used during the computation of gait parameters. The vertical ground-reaction forces (GRF) were normalized to each patient's body weight. The ratio of the affected side versus the unaffected side (a/u ratio) was used as an index of bilateral symmetry for some of the gait parameters. Paired *t*-tests were applied for statistical analysis of differences between with and without shoe lifts. A p value <0.01 was considered as statistically significant.

Figure 1: The subject is wearing the footwear and 15 light-reflecting markers are set according to the Helen-Hays method [5].

Results

Temporo-spatial parameters

Temporo-spatial parameters are shown in Table 2. The walking velocity, cadence and stride length on the affected side with shoe lifts were larger than those without shoe lifts, but their differences were not significant. The a/u ratio for single and total supports had the same effects, but the ratios in the step length, single and total supports were also not significantly different.

Table2: Comparison of temporo-spatial parameters of with and without shoe lifts

	Shoe lifts		
	w/	***w/o***	
Velocity (cm/s)	110.6±13.2	100.1±8.7	ns
Cadence (step/min)	106.2±3.2	104.7±8.8	ns
Stride length (%BH)	78.1±6.3	74.0±4.9	ns
Step length (a/u)	0.932±0.092	0.958±0.076	ns
Total support (a/u)	0.933±0.007	0.892±0.043	ns
Single support (a/u)	0.899±0.008	0.832±0.073	ns

w/:with shoe lift; w/o:without shoe lift; BH: body height

Angular changes

In the trials without shoe lifts, the pelvises of unilateral CDH patients on the affected side remained lower than on the unaffected side after heel strike and during swing stage (Figure 2). In the trials with shoe lifts, the pelvises on the affected side rose significantly throughout the gait cycles, but the affected sides of unilateral CDH patients remained lower than those of the healthy subjects during the heel strike.

Subjects without shoe lifts had more flexion of the knee joints on the unaffected side than those with shoe lifts (Figure 3). Subjects without shoe lifts had more pronation of their ankle joints throughout the gait cycles on the unaffected sides (Figure 4).

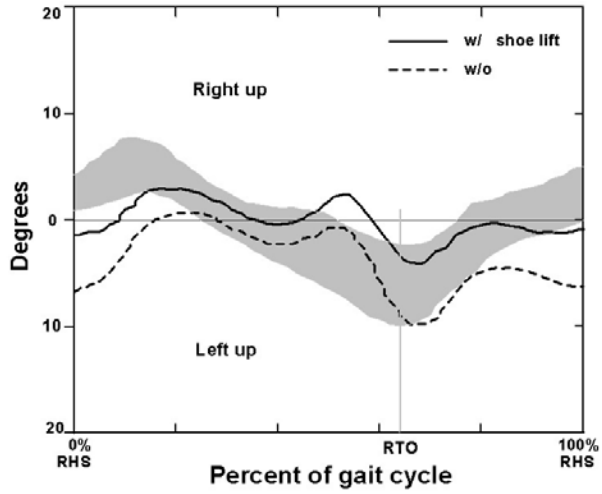

Figure 2: Pelvic obliquity on the frontal plane. The gray area is the mean standard deviation of the healthy subjects.

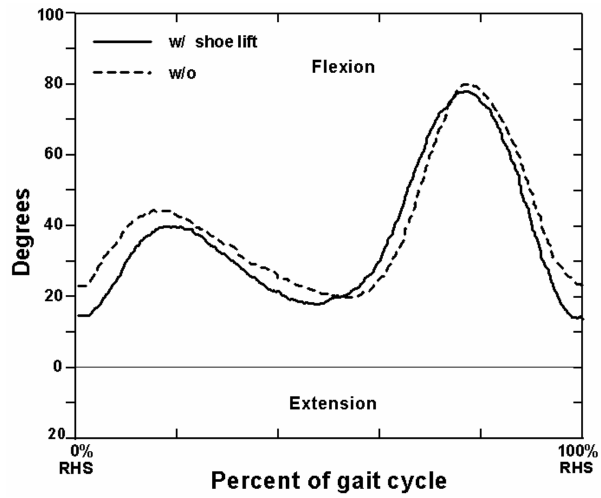

Figure 3: More flexion of the knee joints in the unaffected sides as without shoe lifts on the affected side

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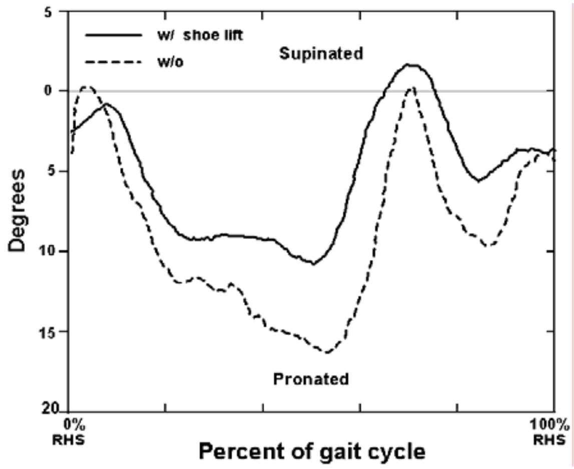

Figure 4: More pronation of ankle joints throughout the gait cycle in the unaffected sides as without shoe lifts on affected sides

Ground-reaction force (GRF)

The GRF curve of the healthy subjects had two peaks during the stance phase, where the first peak occurred before midstance and the other occurred after midstance. The GRF curves of the unilateral CDH patients on the affected sides lacked an obvious peak after midstance. The first peak for those with shoe lifts increased markedly; the peak value of shoe lifts was 2.5 times higher than for those without shoe lifts (Figure 5). A shift of the GRF to the lateral side occurred during the stance phase on the affected sides of those without shoe lifts (Figure 6).

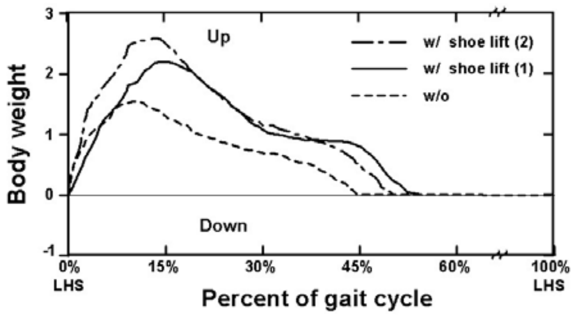

Figure 5: Vertical GRF in affected side during the stance phase

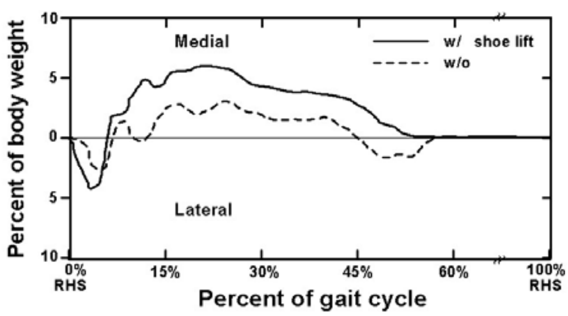

Figure 6: Shift of the medial-lateral GRF in affected side

Discussion

None of the temporo-spatial parameters for patients with and without shoe lifts were significantly different. This unexpected outcome may have resulted from four major compensatory mechanisms during walking. The first compensatory mechanism was that the pelvis dropped with leaning of the ipsilateral aspect of the trunk on the shorter side. This phenomenon was observed from that the pelvis on the side without a shoe lift remained lower than the side with a shoe lift throughout the gait cycle (Figure 2). The second was that the subjects had more flexion of the knee on the longer side to equalize the functional limb lengths (Figure 3). The third was that the pronation effect of the foot on the longer side was obvious to equalize the functional limb lengths (Figure 4). The fourth was that the subject held his or her foot in equine and supination on the shorter side. This compensatory reaction resulted in a shift of the GRF to the lateral side which occurred during the stance phase on the side without a shoe lift (Figure 6). Though the temporo-spatial parameters were not significantly different in our results, they indicated that the addition of shoe lifts resulted in an equalization of the parameters. Moreover, an equalization of compensatory mechanisms between both feet resulted in a reduction of pronatory forces within the longer limb and supinatory forces within the shorter limb.

In the vertical GRF curve during the stance phase, the first peak is an indication of the impact force at and immediately following heel strike as the center of gravity of the body is elevated [6]. In this study, the first peak of the GRF on the side with a shoe lift was markedly increased (Figure 5). This adverse effect may have caused increases of joint stress to the lower limb. This phenomenon may be due to the greater impulse of the heel and outsole of the footwear, which resulted from the increase of material hardness and mass. To diminish the reaction force, the heel and outsole should be made of materials with proper shock-absorbing capability and as little mass as possible.

The GRF curves lacked obvious peaks after midstance in this study (Figure 5). This phenomenon resulted from two major reasons. The first reason was the protective compensation of the CDH subjects who had dysplastic hips. The subjects had reduced push-off force for the affected limbs as adaptation to reduce the load on the joints. This protective compensation was observed in the patients with dysplasia of the hips [7]. The second was the design of shoe lifts in this study. The forefoot rocker had an unfixed point to provide easier and smoother motion during the process of propelling the body forward (Figure 1), however, they reduced the support force for the contraction of the gastrocnemius and soleus muscles and thus the GRF decreased.

Conclusions

Shoe lifts improved the pelvic levelness and eliminated the limp on the leg-length discrepancies for unilateral CDH patients and reduced pronatory forces on the longer limb and supinatory forces on the shorter limb. However, the use of shoe lifts also added vertical GRF, which may cause increased joint stress of the lower limbs. To diminish the contact forces of the shoe lifts, the materials of the heel and outsole should be made of materials with proper shock-absorbing capability and as little mass as possible. A forefoot rocker provided easier and smoother motion during the process of propelling the body forward, but it also diminished the propelling force.

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