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Short-Term Effect of Correcting Leg Length Discrepancy on Performance of a Forceful Body Extension Task in Young Adults

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ABSTRACT

In this study we assessed the short-term effect of correcting leg length discrepancy on a vigorously performed task of resisted full body extension in 10 men, 18 to 35 years old, who had estimated leg length discrepancies of 10–15 mm. Using a cable ergometer we examined work performed, initial peak tension exerted on the ergometer, second peak tension, time to first peak tension, and mean velocity of the whole task. Each subject performed the task both with and without a heel lift, introduced to equalize leg length. The interval between testing under these two conditions was 48 hr. In the task of pulling the cable upward, each subject began from floor level with knees and trunk flexed, progressing to full body extension with the arms pulling the cable overhead with maximal effort. For each trial the task was repeated 15 times, with intervals of 90 seconds between the repetitions. Use of the lift failed to have a statistically significant effect on any of the variables, although it clearly enabled three of the subjects to exert greater strength with the arms and trunk during the second peak tension. This suggests that 1) overall body extension is influenced by too many factors to be affected in a consistently predictable way by a heel lift to correct leg length discrepancy, and 2) the heel lift may aid certain subjects with leg length discrepancy specifically during extension of the trunk in this task.

Key words: *Leg length discrepancy, Heel lift, Body extension*

Leg length discrepancy has been reported to be present in 25 to 93 per cent of the general population[1,5,8,17,26)]. The breadth of these estimates can be attributed to differences in criteria for determining the presence of a discrepancy[3,8–10,15)]. The degree to which a given leg length discrepancy affects someone may depend on activity level of the individual[1)]. A discrepancy of 5–20 mm might initially appear to present little problem to a sedentary individual but could have a more immediately dramatic effect in an active athlete or in someone involved in heavy manual labor[1,6)]. Increased force loads and the stresses of repetitive loading can magnify otherwise subtle effects of leg length discrepancy[1,15)]. The constant repetitive running strides of distance training may lead to any of several injuries. Symptoms allegedly caused by leg length discrepancy include pain in the low back, hip, knee, ankle, and iliotibial band, as well as sciatica[1,9,11,12,14–16,21,26)].

Even though a leg length discrepancy of less than 10 mm might not, to the untrained eye, give rise to a noticeable asymmetry in the body, permanently having such a condition might lead to functional consequences over a long period of time. Leg length discrepancy of 5–9 mm, for example, was found much more frequently among military patients with low back pain than among military personnel without symptoms of pain[9)]. The purpose of the present study was to examine whether the asymmetry induced by a leg length discrepancy might be associated with decreased function in a bilaterally symmetrical task of resisted extension of the body.

One way to alleviate leg length discrepancy is to insert a heel lift into the shoe of the shorter leg to make the lengths of the lower limbs more equal to each other. Both partial and full correction for discrepancy have been reported[1–3,14,17)], but the practice of even using a heel lift at all to correct leg length discrepancy has been questioned[7,25)]. Several authors have suggested that using a heel lift enhances biomechanical symmetry of movement, thereby decreasing the chance of injury in an active individual[1,3,4,26)]. Some have advocated using a lift as a preventive measure[3,13)], based on a correlation between leg length discrepancy and development of osteoarthritis in the knee and hip of the longer limb[3,10,11,22)].

Introducing a lift to alleviate asymmetry might,

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however, actually do disservice to a person who has had a minor leg length discrepancy over a long time. That individual has had plenty of time to adapt to the asymmetrical condition, and suddenly changing the situation with a lift could counter some of the adaptation.

Fisk and Biagent have asserted that moderate degrees of leg length discrepancy play little if any part in the etiology of backache[7]. Gross, in reviewing young adults' perceptions of the functional effects of leg length discrepancy, found that individuals with less than 20 mm difference did not consider the discrepancy to be a problem[14]. In studying leg length discrepancy in marathon runners, Gross concluded that differences of 5 to 25 mm are not always functionally detrimental to marathon runners and that benefits could not be consistently attributed to using a heel lift[15]. In a study by Mincer and associates, leg length discrepancies of 7 to 20 mm had no apparent effect on ability to perform accurately controlled trunk motion during fatiguing flexions and extensions of the trunk[19].

The above underscores the controversial nature of whether leg length discrepancy of less than 20 mm is a predisposing factor to injury in the lower limbs or low back. If leg length discrepancy is a contributing factor in such injuries, then correcting the discrepancy by using a heel lift might improve performance of activities involving effort through the trunk. The present study was designed to determine whether body extension at several joints against resistance is affected by compensating for leg length discrepancy with a heel lift on the side of the shorter leg. In coming up from a squat to elevate a load by the hands, the force exerted by the hands must be transmitted through the whole body (via wrists, elbows, shoulders, trunk, hips, knees, ankles, and feet) to the floor. In this chain of force transmission, the weakest link determines the capability of the entire body to perform the task[18]. The body extension task requires a bilaterally symmetrical performance by the subject; having a leg length discrepancy produces an asymmetrical situation that might hinder this performance. Compensating for leg length discrepancy to restore symmetry and normal musculoskeletal relationships may thus increase capacity to perform the type of task used in this study.

The hypothesis of this study was that young men with leg length discrepancies would exhibit increased capability to perform full body extension against resistance immediately after partial correction by a heel lift. Capability of performance was examined in terms of work output, initial peak tension, a second peak tension, time to the first peak tension, and mean velocity of resisted arm movement during the full body extension.

The motion of forceful body extension used in this study was chosen to put the lumbosacral and sacroiliac regions under dynamic stress so that, if asymmetry due to leg length discrepency has functional consequences, those consequences might become measurable. The task does not necessarily simulate an industrial lifting situation.

MATERIALS AND METHODS

Ten healthy young men, 18 to 35 years of age, with estimated leg length discrepancies of 10–15 mm, volunteered to participate in the study. During the previous two years, none of the subjects had been required to reduce activity or seek medical attention because of pain in the back, arms, or legs. None of them had any cardiovascular disorder. Each subject was informed both orally and in writing about the nature of the study and was advised that medical attention would be sought if overexertion in the experiment led to back strain. Thus informed, each subject freely agreed to participate in the study, which was approved by the Human Subjects Committee at Georgia State University.

To estimate degree of leg length discrepancy, the iliac crests were palpated from behind and thin tiles inserted under one heel until the subject's iliac crests were judged, with the aid of a carpenter's level, to be at equal heights. The total thickness of tiles underneath the heel of the subject's shorter leg served to estimate the degree of that subject's leg length discrepancy[20]. This method, when evaluated against radiographic measurements, has been shown to be more accurate and precise than other clinically used nonradiographic methods to estimate leg length discrepancy[27]. Because of the expense and invasiveness of using radiographic techniques, we opted to rely on this nonradiographic method of estimation for the present study.

Prior to performing the task, each subject exercised mildly for 10 minutes on a bicycle ergometer to warm up. Pedal speed was set to 120 rpm and the subject was instructed to pedal continuously with a comfortable amount of effort.

The task was performed on a Tru-kinetics TK 8330 (Tru-Trac Therapy Products Inc., P. O. Box 850, Temecula, CA 92390). This ergometer had a cable with handle that the subject lifted from a pulley near the floor. The main part of the device, affixed to a platform on which the subject stood, contained the cable and provided resistance to the subject's effort to pull the cable. Insofar as the subject exerted greater tension on the cable, the ergometer's resistance to the cable being pulled likewise increased.

The device provided two forms of output: 1) an analog voltage proportional to the tension exerted on the cable during the task and 2) a digital display on the apparatus itself that showed how much work was performed on the cable at the conclusion of a single repetition. The analog voltage reflecting tension in the cable was digitized at 100 samples per second via an analog-to-digital converter (WATSCOPE, Northern Digital Inc., 403 Albert Street, Waterloo, Ontario, Canada N2L 3V2) and stored for subsequent analysis in a microcomputer. The value on the digital display of the ergometer had to be read visually and recorded by hand after each repetition.

The ergometer could be adjusted to one of ten levels of relative resistance to tension exerted on the cable during the task. In this study the resistance was set to the fourth highest level of the device.

Prior to testing, the subject performed four repetitions for practice. During the first three, the subject pulled the handle through the full range of body extension to feel what the activity would be like. During the fourth repetition, the subject was instructed to pull with a stronger but not excessive effort.

While the subject was practicing the task before actual data were collected, we adjusted the length of a rope suspended from the ceiling so that its end would just touch the subject's hands at the end of the motion, thus providing a target so that the subject would consistently lift the handle to the maximal height.

The subject then performed 15 repetitions for data analysis, with 90 sec of rest interposed between repetitions. On one of two occasions of 15 repetitions, the subject used a heel lift on the side of the shorter leg to partially correct for the leg length discrepancy. On the other occasion, the subject performed 15 repetitions without the heel lift. The two occasions were separated by 48 hr. The ordering of these two sets of 15 repetitions was randomized among the subjects.

The height of the heel lift was determined in a preliminary series of trials, beginning with a height half the subject's estimated degree of leg length discrepancy. The height of the heel lift was then incremented until the subject felt the greatest ease of trunk motion, observed by the investigator during flexions and extensions of the trunk.

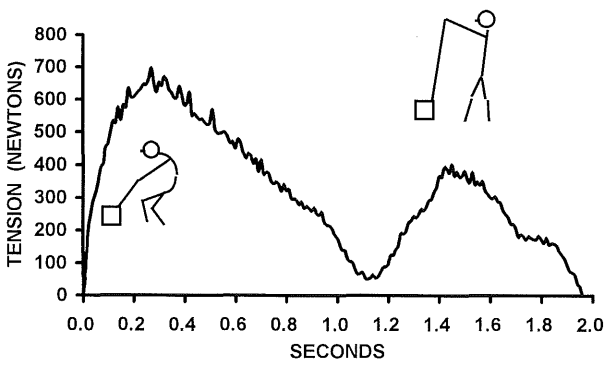

Fig. 1. Typical pattern of tension production in the cable of the ergometer during the body extension task. The subject began from a full squat and lifted the handle of the cable as high as possible. The first peak occurred as the legs were extending, and the second peak as the trunk was extending.

The subject stood with the pulley centered between the feet, which were separated by a comfortable distance for the individual subject. Foot position was maintained constant throughout the repetitions. The subject was instructed to pull the handle of the ergometer as hard and fast as possible toward the target above. We gave the subject strong oral encouragement during each repetition.

Preliminary study revealed that the tension curve could be expected to consistently display two peaks, as shown in Fig. 1. The first peak occurred as the subject was rising from a squat, the second as the arms were raising the cable toward the ceiling. Four dependent variables were examined in the tension curve: 1) amplitude of the first peak tension in the cable of the ergometer, 2) amplitude of the second peak tension, 3) time required to reach the first peak tension, and 4) average velocity of one repetition. The peaks were identified manually with a cursor on the screen of a computer's monitor displaying the tension in the cable. A fifth dependent variable, work per extension, was read directly from the digital display on the ergometer. The data were grouped into three consecutive sets of five repetitions each to see if localized fatigue might play a role.

The data were examined in two-way analyses of variance with repeated measures design. We chose a probability of less than 0.05 as a criterion for rejecting the null hypothesis of no significant difference between using a lift or not using one, or of no significant difference among the three consecutive sets of five repetitions.

RESULTS

None of the five variables examined in this study demonstrated statistically significant differences between performing the body extension task with the heel lift in place and doing it without the heel lift, nor was time a significant factor for any of the five variables.

The probability of making a *type II error*, that is of falsely asserting that the lift had no effect, was retrospectively estimated for each of the five variables without reference to time[24]. Estimates of the type II error ranged from 0.6 to 0.7.

Further examination of the data did reveal an interesting finding for the second peak tension. As Fig. 2 shows, seven of the subjects performed equally well with and without the lift. Three others exerted markedly higher second peak tensions when using the lift.

Variations for the other four variables were more random in nature, not exhibiting two distinct patterns as was seen with the second peak tension.

DISCUSSION

Some interesting observations came to light in the present study, but none of the findings were definitive. The nature of the current findings can be interpreted in a number of ways.

Did the Lift Have a General Effect?

Use of a lift under the shorter leg may have had no effect on the body in any way, because the leg length discrepancies encountered in this study were only 10–15 mm, too small to produce functionally meaningful effects. Such is the point of view of Fisk and Biagent[7] and of Gross[14,15].

The lift may, however, have had an actual effect on how the body extension task was performed, but the effect was not adequately detected. Type II errors in the range of 0.6 to 0.7 leave room for this sort of interpretation, suggesting that more precise measurements or a larger sample might be necessary. Another possibility is that, although the lift may have had a specific functional effect on the body, none of the variables studied adequately reflected this effect. None of these conjectures concerning a general effect of the lift can be adequately addressed without further investigative work.

Two Types of Response

In light of the negative results from a statistical point of view, an alternative approach to interpreting the findings is to examine the data for peculiar characteristics. Figure 2 represents the most striking feature that we found from such an exploration of the data. Inserting a lift under the heel of the shorter leg dramatically helped three men exert higher second-peak tensions, but had no such effect on the other seven subjects. The three

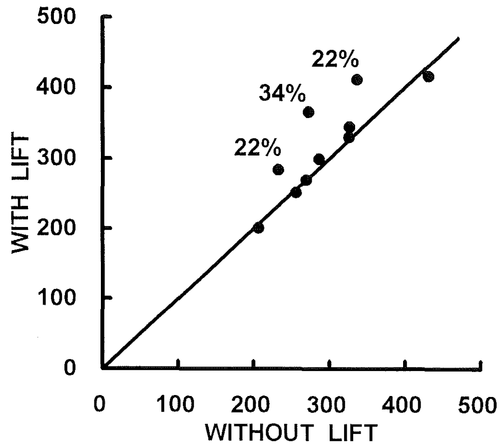

Fig. 2. Comparison of second peak tension in 10 subjects for performance of the task with a lift under the shorter leg versus performance without the lift.
Units are in newtons, and the diagonal line represents no change. Each dot indicates the mean of fifteen trials by one subject. The three percentages indicate, for three subjects, per cent increase in tension obtained when the lift was used compared to when the lift was not used. In the seven remaining subjects, second peak tension when the lift was used was within five per cent of the tension when the lift was not used.

individuals aided by the lift may have been better able to extend the trunk during the second peak because of a more symmetrical configuration of the pelvic and lumbosacral regions, which would have been bearing much of the load in that phase of the body extension task. The remaining seven men, on the other hand, may have resorted to the same strategy as without the lift because of familiarity with a particular way of performing such a motion.

We are unaware of any work related to pelvic mechanics or leg length discrepancy suggesting two or more specific methods of functionally adapting to adjustment of leg length when the pelvis and lower spine are loaded, so the two responses to the lift observed in the present study can only be viewed as suggestive of two specific strategies.

That two distinct responses were observed only for the second peak tension but not for the other variables prompts us to conjecture that leg length discrepancy can exert an influence on the full body extension task principally during trunk extension. Leg length was estimated in this study in terms of relative heights of the iliac crests, so every one of the subjects had pelvic asymmetry when not using a lift. This would in turn tend to give rise to asymmetry in the lumbar spine, unfavorably influencing an effort to lift the cable upward with both arms during trunk extension, because a lumbar spine laterally flexed from the pelvic asymmetry would also be rotated along the spinal axis[23].

In Search of Other Suitable Variables

Although we looked at five variables in relation to this task of full body extension against resistance, only the second peak tension, as discussed above, showed any sign of being influenced by a corrective lift under the heel of the foot of the shorter leg.

The first peak tension and the time to the first peak might have been relatively unaffected by presence or absence of the heel life for two reasons. First, unlike the trunk, a single entity whose extension contributed mainly to the second peak tension, the two lower limbs could make their own separate mechanical adjustments to asymmetry during their principal contribution to the first peak tension. Secondly, when a person strongly extends the legs from a squat, the force is exerted primarily through the forefeet, which would hardly be affected by presence of a heel lift on one side.

Total work and mean velocity, on the other hand, were derived from the entire task. Our data suggest that the lift would exert an effect only in some subjects with leg length discrepancy and that, when present, such an effect would alter only part of the task and not be large enough to be reflected in such global variables as total work or mean velocity.

Further investigation of this task may thus best be oriented specifically at the nature of the trunk extension. Not only should trunk and arm movement be studied more carefully, but also factors related to each subject's leg length discrepancy should be carefully recorded in an effort to identify why some subjects may perform the task differently than others.

CONCLUSIONS

Lifting a cable against resistance from a full squat to upright standing with the arms overhead produced two peaks of tension in the cable: a larger peak when the legs were extending and a smaller peak when the trunk was extending with the arms reaching upward.

Inserting a corrective lift under the heel of the foot of the shorter leg had no general mechanical effect on the task as a whole.

The corrective lift may have produced two different patterns of response in the second peak of tension in the cable. In some subjects, tension during the second peak was remarkably greater when a corrective lift was used, whereas in other subjects the lift had no such effect. This finding requires confirmation.

Further investigation should focus only on the trunk extension phase of the task and on classifying subjects with leg length discrepancy.

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