Development of Trail Walking Shoes by Using Biomechanical Evaluation

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ABSTRACT

Objective: The purpose of this study was to measure the influence of the trail walking shoes on walking biomechanics (muscle activity, cushioning and joint loading) during hiking movements. **Background:** Hiking on hard, ragged, and rocky surface can cause foot injury, furthermore, long-time hiking can aggravate foot fatigue. As hiking on uneven surface involves the risk of injury, wearing specially designed performance shoes is recommended. **Method:** Five male subjects completed a level walking movement while wearing three different hiking shoe conditions: a Control-A shoe, a Control-B shoe and the Normal shoe. **Results:** The knee joint loads are generally lower with the Normal shoes. Since these loads have been associated with the development of osteoarthritis in the knee joint, a reduction with the Normal is a strong positive effect. With the Normal shoe, some of the ankle joint loads were lower while some were higher than with the other shoes. The cushioning of the Normal shoes was similar to the other shoes tested. Peak forces in the medial and lateral direction were lower with the Normal shoe in comparison to the other shoes. Medio-lateral forces provide an indication of stability and the decreased peaks in these directions suggest that the Normal shoe provides good stability, which could be why the overall muscle activity while wearing the Normal shoe is generally decreased. **Conclusion:** The results of this study show that the Normal shoe had lower overall muscle activity during level walking when compared to the Control-B shoes, by as much as 3%.

Keywords: Trail Walking Shoes, Muscle Activity, Cushioning, Joint Loading

1. Introduction

Trail walking is one of the most fast-growing industries recently, and the demand for experiencing nature seems to increase further (Breejen, 2006; Mehmetoglu, 2007; Nyaupane, Morais and Graefe, 2004). Hiking on hard, ragged, and rocky surface can cause foot injury, furthermore, long-time hiking can aggravate foot fatigue (O'Loughlin, Murawski, Egan and Kennedy, 2009; Park and Lee, 2007; Stewart, Casey, Laura, Patricia, Edward, James and Joseph, 2009). As hiking on uneven surface involves the risk of injury, wearing specially designed performance shoes is recommended (Hettinga, Stefayshyn, Fairbairn and Worobets, 2005). Studies on influence of shoes have been made in various fields such as muscle activity, motion control, exercise performance (Harald and Matthias, 2009; Menz and Sherrington, 2000; Murley, Landorf, Menz and Bird, 2009; Nigg, Hintzen and Ferber, 2006; Romkes, Rudmann and Reinald Brunner, 2006; Stefanyshyn and Nigg, 2000). Based on the precedent studies, we intended to find out biomechanical performance of the trail walking shoes. Therefore, the purpose of this study was to measure the influence of the Normal shoes on walking biomechanics (muscle activity, cushioning and joint loading) during hiking movements.

2. Method

2.1 Subjects

Five subjects, 5 male, were used in this study. All subjects were free from any lower limb injury and signed informed consent forms by the University of Calgary prior to the study.

2.2 Testing Shoes

Five male subjects completed a hiking movement while wearing three different trail walking shoe conditions: a Control-A shoe, a Control-B shoe and the Normal shoe(Figure 1).

Figure 1. Test shoes
(From left to right : Control-A, Control-B, Normal)

Figure 2. Photograph of a subject during data collection

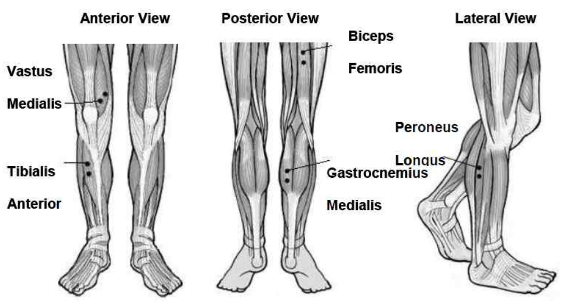

Figure 3. Schematic showing the muscles where EMG was measured during the investigation

Figure 4. Photographs of the EMG electrodes and reflective markers used for data capture during walking

2.3 Data Collection

The hiking movement was level walking over a smooth surface(Figure 2). During these walking trials, EMG activity of five muscles were measured: Tibialis Anterior, Peroneus Longus, Gastrocnemius Medialis, Vastus Medialis, and Biceps Femoris(Figures 3, 4).

In addition, kinematic and kinetic data were collected. A total of ten steps were recorded per subject / shoe / movement, and average values were calculated. As only five subjects were tested in this study, no statistical procedures were employed. During the walking trials, the motions of spherical reflective markers attached to the shoe and the subject's leg(Figure 4) were captured with an eight camera high speed Motion Analysis system operating at 240 Hz, and the ground reaction forces of one right foot-strike were measured with a Kistler force platform operating at 2,400 Hz. The video and force data were analyzed using Kintrak software. An inverse dynamics analysis was performed using the kinetic and kinematic data to calculate three dimensional joint moments at the ankle and knee.

3. Results

3.1 Muscle Activity

The graph in Figure 5 shows the average muscle activity of all five muscles combined. These results suggest that the Normal shoe had lower overall muscle activity during level walking when compared to the Control-B shoes, by as much as 3%. The graph in Figure 6 shows the individual activities of each of the five muscles. In general, the Normal shoe decreased the activity of the Biceps Femoris and Tibialis Anterior muscles(BF, TA) and increased the activity of the Peroneous Longus(PL) muscles. In the original prototypes, PL muscle activity was decreased so it is unclear why the new versions of the Normal shoe increased this activity. However, overall, the results of this study suggest that during level walking, the Normal shoe decreased the activity of the lower leg muscles.

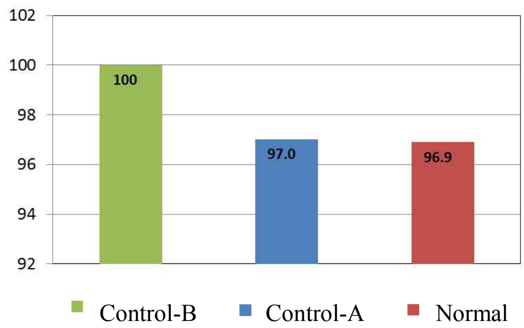

Figure 5. Relative muscle activity among the three shoes during the hiking movement. Each value is expressed relative to the Control-B condition. Each bar is the average of all five muscles and all five subjects

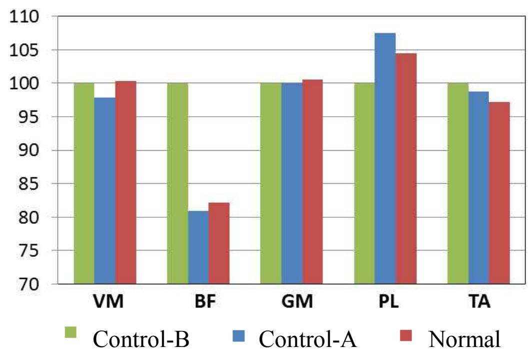

Figure 6. Relative muscle activity of each of the individual muscles for the three shoes during the hiking movement. Each value is expressed relative to the Control-B condition. Each bar is the average of all five subjects

3.2 Joint Loading

The frontal plane knee joint loading(peak abduction joint moments) and transverse plane knee joint loading(peak rotation moments) are generally lower with the Normal shoes(Figure 7). These moments, especially in the frontal plane have been associated with the development of osteoarthritis in the knee joint so a reduction in the joint loads with the Normal footwear is a strong positive effect.

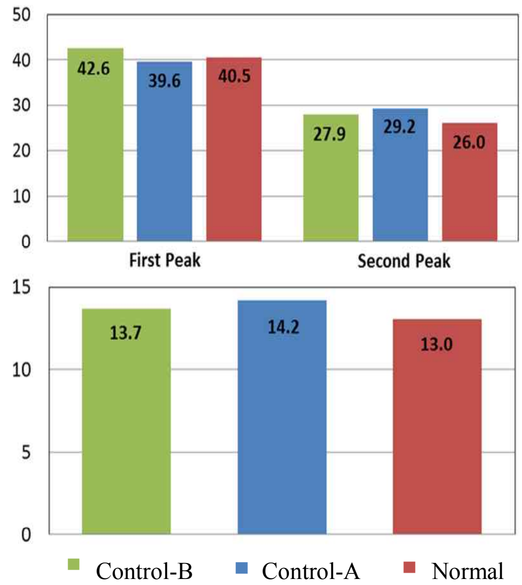

Figure 7. Knee joint loading data. Top graph: peak abduction moment(frontal plane loading). Bottom graph: peak external rotation moment(transverse plane loading). Each bar is the average of all five subjects

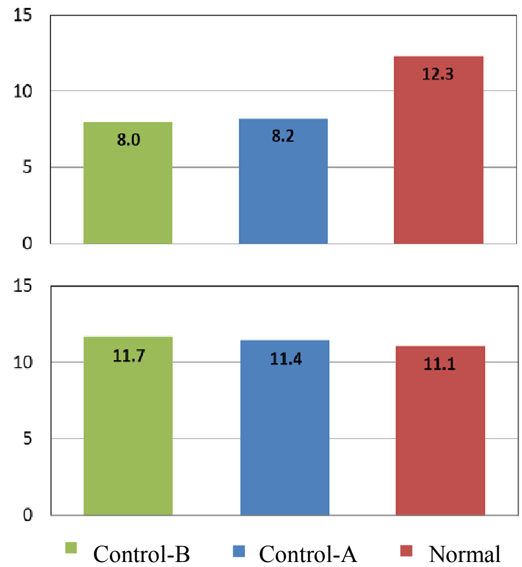

Figure 8. Ankle joint loading data. Top graph: peak external rotation moment(transverse plane loading). Bottom graph: peak inversion moment(frontal plane loading). Each bar is the average of all five subjects

The ankle joint moment data are shown in Figure 8. The Normal shoe had lower rotation moments (transverse plane) but higher inversion moments(frontal plane). Similar to the knee moments, the general aim of footwear is to try to decrease the loading in these planes to decrease the likelihood of injury. However, it is common to see an increase in frontal plane ankle moments when decreasing frontal plane knee moments, which are generally believed to be more relevant for injuries. The increased frontal plane moments also correspond well with the increased muscle activity of the peroneus longus muscle which helps stabilize the ankle joint in the frontal plane.

3.3 Cushioning

The cushioning of the Normal shoes was similar to the other shoes tested(Figure 9). Peak forces in the medial and lateral direction were lower with the Normal shoe in comparison to the other shoes. Medio-lateral forces provide an indication of stability and the decreased peaks in these directions suggest that the Normal shoe provides good stability, which could be why the overall muscle activity(EMG) while wearing the Normal shoe is generally decreased.

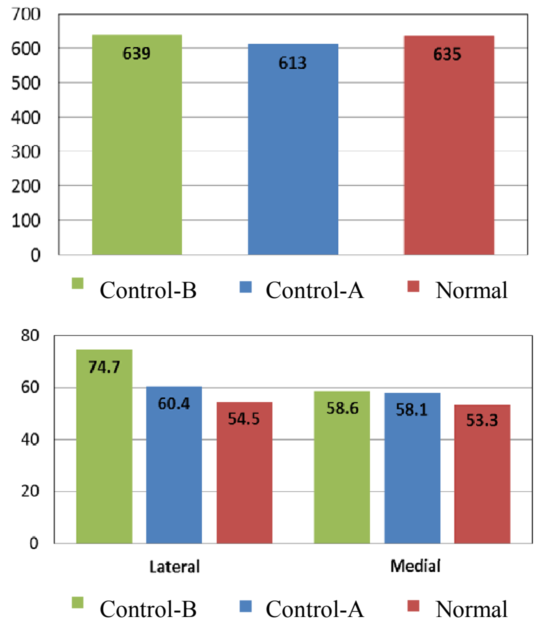

Figure 9. Ground reaction force data. Top graph: peak impact force(vertical direction). Bottom graph: peak lateral and medial forces. Each bar is the average of all five subjects

4. Conclusion

In general, the Normal shoe decreased the activity of the Biceps Femoris and Tibialis Anterior muscles and increased the activity of the Peroneous Longus muscles. In the original prototypes, Peroneus Longus muscle activity was decreased so it is unclear why the new versions of the Normal shoe increased this activity. However, overall, the results of this study show that the Normal shoe had lower overall muscle activity during level walking when compared to the Control-B shoes, by as much as 3%. The knee joint loads are generally lower with the Normal shoes. Since these loads have been associated with the development of osteoarthritis in the knee joint, a reduction with the Normal footwear is a strong positive effect. With the Normal shoe, some of the ankle joint loads were lower while some were higher than with the other shoes. In general these loads should also be decreased to try to avoid injury but since the loads at the ankle are much lower than at the knee, they are not as critical. Some of the increased ankle loads would help explain the increased muscle activity of the peroneus longus muscle which helps stabilize the ankle joint in the frontal plane. The cushioning of the Normal shoes was similar to the other shoes tested. Peak forces in the medial and lateral direction were lower with the Normal shoe in comparison to the other shoes. Medio-lateral forces provide an indication of stability and the decreased peaks in these directions suggest that the Normal shoe provides good stability, which could be why the overall muscle activity while wearing the Normal shoe is generally decreased.

Acknowledgements

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