Biomechanical Effects of Men's Dress Shoes Made with Eco-Friendly Materials

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Footwear design and development can either help or hinder foot health. Not only do footwear designers consider promoting healthy and functional feet, but they also aim to fulfill consumer demands for various styles of shoes. For the shoe makers, it is also important to engage in intentional design practices and choose suitable sustainable materials for shoe making if considering environmental sustainability beyond the wearers' fit and comfort. Functional footwear is generally designed to be comfortable and stable for body posture and gait to facilitate easy walking and feet protection. Although biomechanics studies have been performed to investigate the effects of footwear (e.g., insole, outsole, heel) during walking using a kinematic and kinetic approach, rarely do shoe designers and researchers investigated wearer' performance with comparing a sustainable shoes prototype with commercially available shoes using human wear trials. Therefore, the purpose of this study was to evaluate wearers' performance in men's leather shoes comparing with the sustainable shoes using an experimental research design. We hypothesized no differences in kinetic and kinematic parameters of gait within lower extremity of participants when wearing two different shoes, while performing the following three conditions: walking on flat ground, ascending stairs, and descending stairs.

Nam and Lee (2017) found a great potential of multi-layered cellulosic materials (MCM), consisting of cellulosic fiber mat, hemp, and denim, for the use of a leather alternate. For this study, we adapted their material configuration and designed a sustainable shoe prototype made with the MCM for outer, mid, and inner shells and other materials for midsole (i.e., compressed paper) and outsole (i.e., cork). Commercial leather shoes were made by one of independent shoe companies using the identical patterns with our sustainable shoe prototype. The average weight of the sustainable shoes and leather shoes were 1.34 ± 0.01lb and 1.64 ± 0.06lb, respectively.

Data collection was started after obtaining the use of human subject approval. Total 42 healthy male participants were recruited from one of a large Midwestern university. Among those, 37 (age 25 ± 7years; height 68.90 ± 1.97inch; mass 170.95 ± 25.35lb) was used for the data analyses. The sample size reached a 0.84 power level with an effect size of 0.5 at $p < 0.05$. The participants consisted of 19 Asian, 16 Caucasian/European American, and two Hispanic American/Latino.

Participants first performed a warm-up protocol and completed a short web-based survey questionnaire eliciting participants' demographic characteristics. Their body measurements (i.e., weight, height, foot) were then obtained. Each participant randomly wore both the leather shoes and sustainable shoe prototypes and then performed the three conditions given, based on a counterbalanced ordering to prevent bias in this experimental research design. To measure and record the human subjects' body movements, 21 retroreflective markers were attached to each human subject's lower extremity, at the pelvis, and shoulders. The participants performed a total

of three trials for three distinct movements. A paired sample *t*-test using SPSS 21 software was performed to compare the effect of wearer's lower extremity between the leather shoes and sustainable shoes on kinetics (ground reaction forces) using four force plates and kinematics (stance time, range of motion) using a 3D motion capture with eight cameras for each condition.

As shown in Figure 1, the mean of vertical ground reaction force (GRF) yielded at the beginning (20%) of the stance phase were higher during participants' descending stairs than for other conditions. The results of *t*-test showed the values of GRF had higher mean score for sustainable shoes (M_S) than that of leather shoes (M_L) in general. Statistically significant mean differences ($MD = M_S - M_L$) between the two shoes at the peak values of GRF during participants' walking on flat ground ($MD = 0.03$) and ascending stairs ($MD = -0.02$) were found ($p < 0.05$). Similar to our findings, Chiu and Wang (2007) reported wearing shoes with a rounded shape outsole had positive effects on lowering the GRF over shoes with flat outsoles during walking on flat ground and ascending stairs in terms of GRF. In this study, the thick material of curve shape outsole for leather shoes was polyurethane, while the thin material of flat shape outsole for sustainable shoes was cork. For GRF, however, no statistically significant mean differences between the leather shoes and sustainable shoes during descending stairs were found. Therefore, it can be stated that the shock absorption effectiveness in outsole of shoes can be similarly performed for both the shoes during descending stairs than for walking on flat ground and ascending stairs, regardless outsole's thickness and material composition.

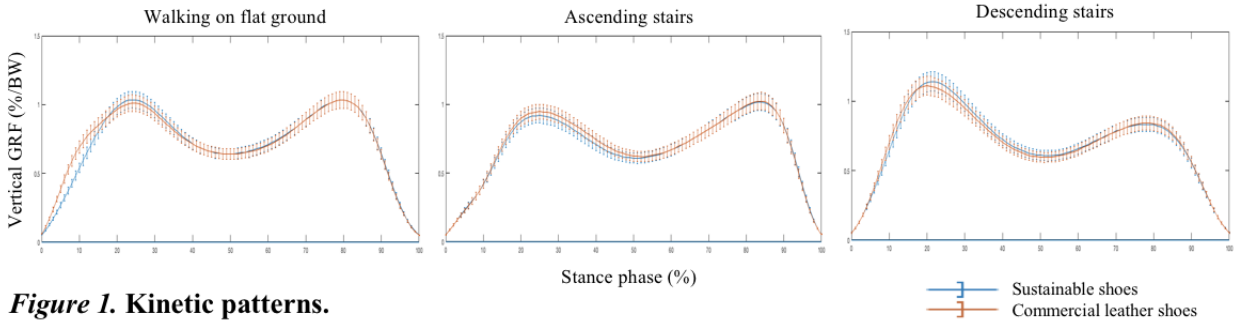

Figure 1. **Kinetic patterns.**

In terms of kinematics, the results demonstrated that stance time for the three conditions showed no significant mean difference between the two shoes. Peak angles in range of motion (ROM) of hips and ankles only during walking on flat ground yielded statistically significant mean differences between the two shoes ($MD_{hips} = 1.1$; $MD_{ankles} = 2.0$, $p < 0.05$). For ROM, the weight of the shoes could affect hips and ankles rather than knees on lower extremity during walking on flat ground. However, no statistically significant differences for peak angles of hips, knees, and ankles were found between the two shoes during ascending and descending stairs.

This experimental study presented the possibility of men's sustainable dress shoes made with MCM as a leather alternate in terms of kinematics and kinetics, due to its parameters to be similarly performed wearers' lower extremity in different conditions compared to the leather shoes. The results also provided a better understanding of the influence of materials of a sustainable shoe prototype on wearers' lower extremity. This study urges to perform users' wearable perceptions and acceptance of the sustainable shoes as a future research.

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References

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