DEVELOPMENT OF A COMPREHENSIVE MEASUREMENT SYSTEM OF SHOE INSOLES ON DYNAMIC HUMAN ACTION: A PILOT STUDY

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The present study aimed to produce a new comprehensive measurement system to clarify the effect of shoe insoles on human dynamic action. Specifically, we attempted to determine the effects of insoles on back strength using a novel device. This measuring system includes a 3D foot scanner and foot pressure mat combined with a strength measurement device. The latter combined device allowed measuring the underneath foot pressure change during strength exertion. Among five types of insoles, three participants consistently exhibited the largest back strength when wearing an insole having serially support three arches in the hind foot. This finding might confirm our proposed the current measuring system is capable to detect the effect of insoles on human dynamic action such as the back strength.

KEYWORDS: insole, back strength, foot pressure, 3D foot scanner

INTRODUCTION: The usage of advanced technology such as three-dimensional digital measurement devices in footwear is becoming popular. For example, data from these devices allow shoe manufactures to produce data-driven shoe lasts and insoles. These novel attempts are setting a new trend of shoe manufacturing process, in which they come to rely more on digital data of human feet instead of traditional plaster work for making shoe lasts or insoles. In general, insoles have been recognized as an effective tool to lowering knee joint load during pathological gait (Jones et al., 2013; Sawada et al., 2016). Some shoe insole companies also claim their efficacy for enhancing dynamic human action. However, the design of these insoles has largely been a trial and error process. In fact, although a few studies confirmed the effect on ankle stability (Hamlyn, Docherty & Klossner, 2012), there is no study quantified the effect of insoles on dynamic human action such as maximum strength exertion. Thus, the effect of insoles on dynamic human motion is still very trivial to date. Insoles that possess actual functionalities (more than gimmicks) to correct malalignment of the foot likely reinforce the performance of dynamic human action. However, there is little quantitative information available regarding the effects of insoles on dynamic human action.

To ease the workload of manual laborer is another important issue to be solved. Excessive load on their body parts during working has been considered as an essential cause of occupational disease or chronic pain on specific body parts such as low back pain. A few studies targeted to record the effect of insoles on lowering workload or chronic pain. Caravaggi and colleagues (2016) found that custom insoles based on foot shape allow for more even pressure distribution in safety-shoes. Jefferson (2013) reported the effect of insoles on the subset of 40 workers was to lower low back pain by 38%. However, the knowledge on how insoles ease low back pain of workers is still limited.

To examine the effectiveness of shoe insoles in various tasks quantitatively, a simple, sensible and comprehensive measurement system is in need. In the present study, we proposed a new measurement system, which includes three dimensional foot scanner and foot pressure mat combined with strength measurement device. The purpose of the present study, therefore, was to propose this measurement system as an effective tool to detect the quantitative effect of insoles on human strength exertion. In addition, the latter combined device allowed measuring the underneath foot pressure change during back strength exertion. From this measurement system, we tried to extract the effect of foot shapes and insoles on foot pressure changes and back strength exertions.

METHODS: A comprehensive measurement system proposed in the present study is shown in Figure 1. As shown in the right panel, a foot 3D scanner (Dream GP Inc., Japan) allowed measuring three-dimensional foot shape below ankle less than 15 s.

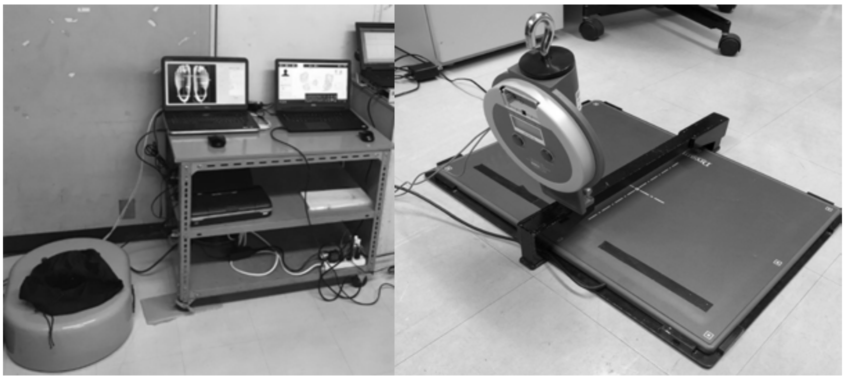

Figure 1. Photo of current measuring system. Foot 3D scanner (left panel) and foot pressure mat combined with strength measurement device (right panel).

As the first step of the measuring procedure, two conditions of the foot shape were measured using this device (Figure 2). In the first condition, participants were in a sitting posture. In the second condition, the foot shape was measured in standing 100% of weight bearing to detect the change of foot shape due to weight bearing.

Figure 2. Two postures used to measure foot 3D shape.

Measurement of foot pressure (RSscan Inc., Belgium) was conducted during still standing and repetitive stamping on the spot. This measurement allowed detection of static and dynamic pressure distribution.

Figure 3. Two postures used to measure foot 3D shape.

The final measurement in the current protocol is the measurement of back strength with foot pressure measurement (Figure 4). A specially made test rig (Figure 1, right panel), which has a solid crossbeam in the center was used. This test rig allowed measuring the time series change of back strength and foot pressure simultaneously.

Figure 4. Photo illustrating the testing apparatus when the back strength and underneath foot pressure were measured simultaneously.

To check the usability of these series of measurements, a pilot test was conducted using three adult male subjects. Following the first two tests, back strength of these subjects were measured in five shod conditions with different types of insole: 1) insoles attached to the tested shoes; 2) ready-made insoles (BMZ Inc., Japan); 3) insoles for standing workers (Dream GP Inc., Japan); 4) insoles for people walking on a daily basis (Dream GP Inc., Japan); and 5: medical wedge insole for flat foot (Dream GP Inc., Japan). Before measuring, these insoles were installed into the same shoes, and back strength of the five insole conditions were measured in a randomized order.

RESULTS and DISCUSSION: Figure 5 shows comparisons of back strength between the five conditions. The time series force curves and the magnitudes of force were varied among subjects. These changes might represent individual differences in physical fitness levels.

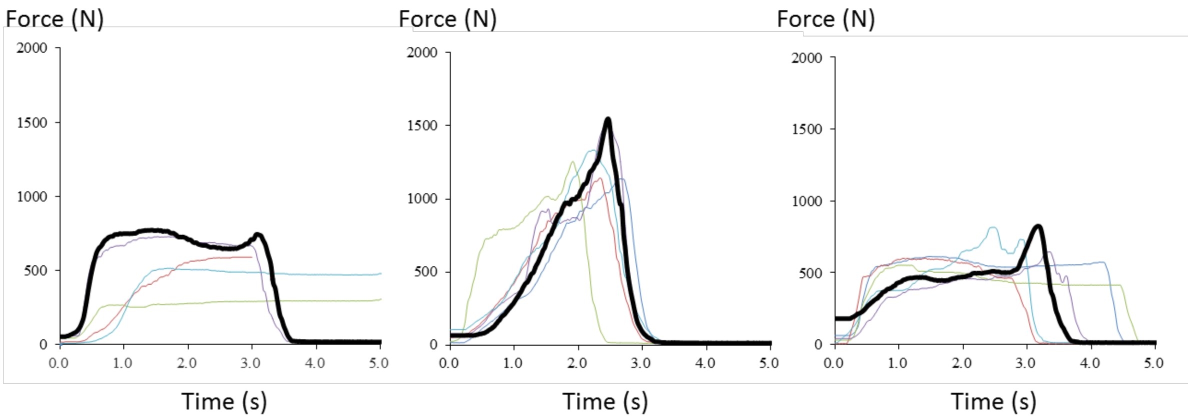

Figure 5. Time-series change of back strength for three subjects.

Interesting to note, among five types of insoles tested in the present study, the participants consistently exhibited the largest back strength (shown as bold lines in the Figure 5) when wearing the insoles for standing workers (condition no. 3) having serially support three arches in the hind foot. It can be assumed that this insole has a better possibility to emphasize human strength exertion due to its unique features than the other insoles. However, further studies to examine the effect of insoles with more number of subjects should be warranted. Additionally, our proposed measuring system and procedure to detect the effect of insoles are capable to detect the difference in the magnitude of back strength between insole conditions.

CONCLUSION: In the present study, we proposed a new comprehensive measurement system to extract the effectiveness of insoles on human dynamic action (maximum back strength). Through a pilot work, the current measuring system showed a good possibility to distinguish the different effects of insoles on the back strength.

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