A METHOD OF MEASUREMENT AND EVALUATION OF THE MECHANICAL PROPERTIES ON THE STABILITY OF RUNNING SHOES

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INTRODUCTION

It is generally thought that high impact forces and excessive foot pronation are connected with foot injuries in running. Major requirements needed for running shoes are reduction of impact forces at touchdown and provision of mediolateral stability (Nigg and Morlock, 1987). Performance of good running shoes should be focused on a balanced reduction of impact forces and over pronation (De wit, De Clercq and Lenoir, 1995). One of the evaluation methods, especially for stability, is rearfoot motion analysis during ground contact in running by high-speed camera (Nigg and Morlock, 1987, et al). Although this method could be effective, however, it is considered that the accuracy of test results could be affected by several factors, such as the repeatability of foot movement by an identified subject or subjects' features. Therefore, in this study, a method of measurement and evaluation of stability is proposed to investigate correlations between the runners' sensory evaluations of shoe and the typical parameters such as torsional rigidity and stiffness of shoe sole.

PROCEDURES

Torsional rigidity was calculated from measured torsional moment of the shoe. The angular displacement was applied by rotating the lever fixed perpendicularly to the steel bar on which the strain gauges were attached as shown in Figure 1. The toe of the shoe was rotated by a clamper on the steel bar while the rear of the shoe was fixed. 20 degrees of angular displacement were applied and the angular inversion and eversion of the forefoot with respect to the rearfoot were measured three times.

Measurement of sole stiffness of the shoe on the shoe last was conducted to investigate the influence of the geometrical shape and construction of shoe sole. In this test, the deformation of the shoe sole was obtained by pressing the indenter of 20mm in diameter against the sole and was measured by an optical displacement transducer. A constant load (about 210 N) applied by air cylinder was measured by a load cell connected to the indenter as shown in Figure 2. Stiffness was defined by the ratio of constant load to maximum deformation of the sole. Stiffness measurements were taken at eight points as shown in Figure 3.

The tests of torsional rigidity and stiffness were carried out on 4 types of running shoes that had the same construction except the hardness of the midsole material (EVA; Asker-C hardness 49.9, 55.3, 60.5 and 66.1), and three types of commercially-available running shoes.

Sensory evaluations were carried out by seven trained male long-distance runners and the results compared using Scheffe's method of paired comparison. First, subjects evaluated the shoes by making relative comparisons by the six possible combinations of

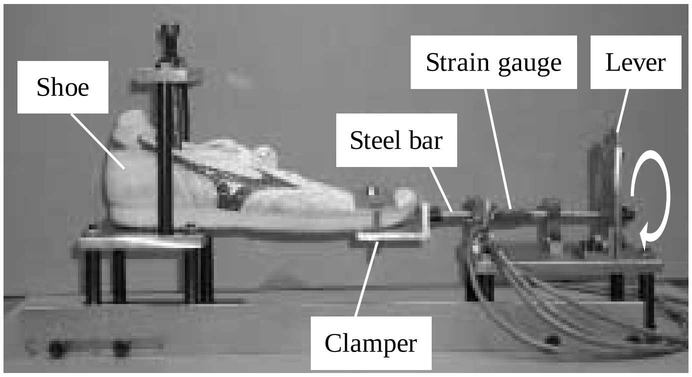

Figure 1 Shoe torsional rigidity testing apparatus

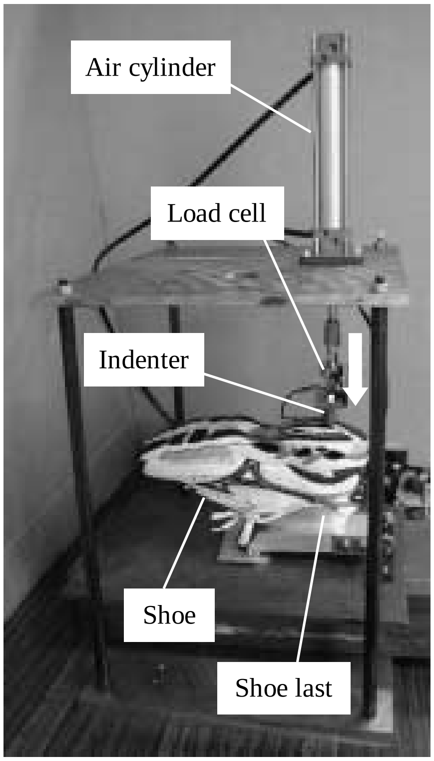

Figure 2 Stiffness of shoe sole testing apparatus

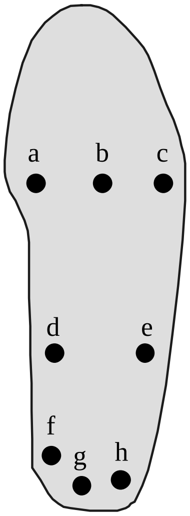

Figure 3 Locations of point of sole stiffness measurement

the four types of shoe which had different midsole hardness. Next, subjects evaluated three possible combinations out of the three types of commercial shoes. Subjects rated stability by running on an asphalt surface. The rating scale had seven steps, from –3 (unstable) to +3 (rigid). Data processing for sensory evaluations was conducted using Scheffe's method.

RESULTS AND DISCUSSION

Table 1 shows the average stiffness of fore sole at points a-c and rear sole at points d-h. The average stiffness of the four types of shoes (Shoe ID = A1, A2, A3 and A4) is proportional to the Asker-C hardness of the midsole at all points. Sensory evaluation results on stability in the case of the four type shoes became better as the sole stiffness increased. Significant differences in sensory evaluation were especially observed in the results of two cases - between shoe A1 and A4, between shoe A2 and A4. Consequently, sensory evaluation results seemed to depend on the stiffness of the sole when shoes have the same sole construction.

Table 1 The average stiffness of shoe sole

Shoe ID (Asker-C hardness)	Average stiffness of fore sole (a-c) [kN/m]	Average stiffness of rear sole (d-h) [kN/m]
A1 (49.9)	26.6	22.1
A2 (55.3)	30.5	25.1
A3 (60.5)	33.1	28.2
A4 (66.1)	37.5	31.3
C1	25.3	25.1
C2	25.0	24.8
C3	25.4	32.6

Figure 4 shows the correlations between the stiffness of rear sole and the sensory evaluation results in case of three types of commercially-available shoes. The stiffness of the rear sole of shoe C2 was distributed more widely than that of shoe C1 or C3. According to the distribution data, the stiffness of medial points (d, f, g) was larger than that of the lateral point (h) in case of the rear sole of shoe C2. On the other hand, the sensory evaluation result of shoe C2 was better than that of shoe C1, even though the average stiffness of rear sole of shoe C1 and C2 was almost the same. By considering the above results, it is estimated that the stiffness of medial points can affect critically the sensory evaluation results on stability, because a harder sole of at the medial foot could reduce excessive foot pronation due to the decrease of the deformation of shoe sole. In the case of shoe C3, sensory evaluation results became the highest, even though stiffness was distributed narrowly. The reason is estimated why the stiffness of rear sole of shoe C3 was much larger than that of shoe C1 or C2.

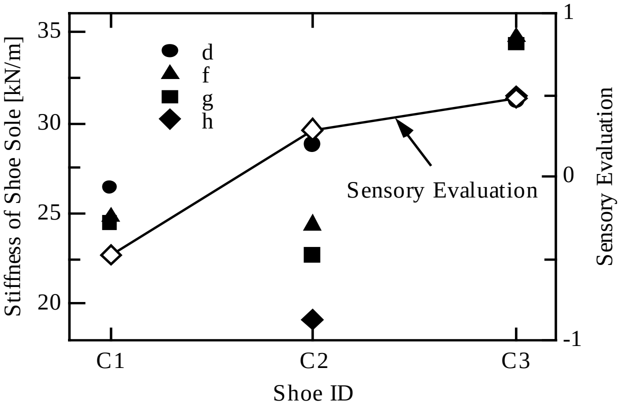

Figure 4 Correlation between the stiffness of the rear sole and the sensory evaluation on the commercial shoes

Figure 5 shows the correlations between the torsional rigidity and the sensory evaluation results in the case of 3 types of commercial shoes. Sensory evaluation became better as the torsional rigidity for eversion increases. On the other hand, the tendency of inversion was not similar to that of eversion. Thus, it is considered that the correlations between torsional rigidity and the sensory evaluation cannot be explained clearly.

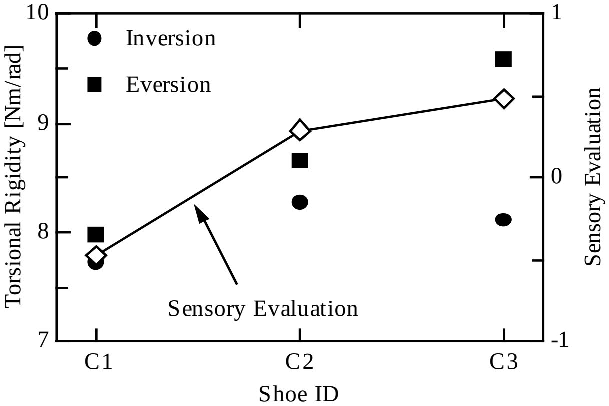

Figure 5 Correlations between the torsional rigidity and the sensory evaluation on the commercial shoes

CONCLUSIONS

Stability of running shoes could be evaluated by the mechanical properties and especially the stiffness of shoe sole could affect the runners' sensory evaluations on stability. Runners seemed to be sensitive not only on the stiffness but also to the distribution of stiffness across the sole of the shoe.

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