INFLUENCE OF SHOE MIDSOLE MATERIAL HARDNESS ON PERCEIVED COMFORT, REARFOOT MOTION, AND PLANTAR PRESSURE

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The purpose of this study was to determine the influence of different midsole hardness on perceived comfort, rearfoot motion, and plantar pressure. Fifteen injury-free male amateur runners participated in this study. Rearfoot motion, plantar pressure, and perceived comfort were recorded while running. Smaller rearfoot maximal pronation, lower comfort scale, and greater maximum force and peak pressure of the lateral side were found in the harder shoe. In the harder midsole shoe, greater force and pressure were found in the lateral side of the midfoot and the forefoot, which may be attributed to a smaller pronation.

KEY WORDS: shoes, rearfoot movement, pressure, comfort

INTRODUCTION:

In running, impact forces occur due to the collision of the foot with the ground. Properties of athletic footwear have been linked to the prevention of injures and comfort in running (McKenzie *et al.*, 1985; Riddle *et al.*, 2003). Excessive rearfoot motion, shock, high impact force, and high pressure in the plantar are discussed as main factors in running injuries (Barr & Harrast, 2005). Therefore, researchers and manufacturers were tasked to reduce the negative effects of running shoes by employing different construction features and material.

Shoes with different midsole hardness were studied. Most studies supported the idea that different midsole hardness did not affect the kinematics parameters observed in the sagittal plane (Hamill *et al.*, 1992; Hardin *et al.*, 2004; McNair & Marshall, 1994; Milani *et al.*, 1997). Some researchers found that kinematics adaptations occurred with the change in midsole hardness of the shoes (Hardin et al., 2004; McNair & Marshall, 1994; Milani et al., 1997). Furthermore, some studies suggested that the body sensory and neuromuscular system seems to differentiate well between the impact of different frequency contents (Milani et al., 1997; Nigg & Liu, 1999; Wakeling *et al.*, 2002). It was also observed that shoes with a softer midsole exhibited greater pronation values and shorter times to reach maximum pronation (Hamill et al., 1992; Kersting & Bruggemann, 2006; Wit *et al.*, 1995). Certain studies found that midsole hardness does not influence magnitude and loading rate of the external vertical impact force (Kersting & Bruggemann, 2006; Nigg & Liu, 1999). Impact magnitudes as determined from the ground reaction force (GRF) and in-shoes forces, however, did not change in the same manner when the hardness of a running shoe was altered. Significant differences were only observed in extreme alterations of midsole hardness (Kersting & Bruggemann, 2006). The largest collection of work on midsole material and control balance was done by Robbins et al. (1994). Midsole hardness was positively related to stability. Yet, some studies showed contradicting results with regard to control balance (Lord *et al.*, 1999; Perry *et al.*, 2007).

Although studies on the influence of midsole hardness on human movement in terms of its kinematic, kinetic, and balance have been conducted, a systematic study on perceived comfort, rearfoot motion, and plantar pressure when people run in shoes with different midsole hardness has not yet been reported. Hence, the purpose of this study is to determine the influence of different midsole hardness on perceived comfort, rearfoot motion, and plantar pressure.

METHOD:

Shoes: Prototype running shoes (made by a professional shoes manufacturer) that differ only in the midsole (same material, but different in hardness) were used in this study. The midsole hardness was measured based on the Asker C hardness scale (hardness of A shoe=50; hardness of B shoe=60). Each subject was assigned 3 pairs of shoe in each midsole for to doing comfort, rearfoot movement and plantar pressure tests.

Subjects: Fifteen injury-free male amateur runners participated in this study (Age = 20.27±1.53 years; Body mass: 62.51±9.07 kg; Height: 173.29±5.03cm). All subjects were heelstrikers and their shoe size was 41-43 (Europe). Participants signed informed consent forms. The study was approved by the local institutional review board.

Data collection:
Rearfoot Movement Test: The subjects were asked to run on a treadmill at 3.8m/s. A video camera (9800, JVC) with sampling frequency of 200Hz was situated posterior to the treadmill to record the rearfoot movement during testing. Four light reflective spherical markers were attached to the subjects and the shoes with reference from the methods of previous studies (Cheung & Ng, 2007; Nigg & Morlock, 1987). The first marker was glued over the Achilles tendon 4 cm above the ankle joint. The second marker was placed at mid-distance on a line defined by the bisector of the knee and the marker on the Achilles tendon. The third marker was placed at center heel cap at the insertion of the Achilles tendon. The fourth marker was attached to the center of the heel cap just above the shoe sole. The subjects then ran for 3 minutes in each shoe, and 10 footstrikes of the last 30 seconds were filmed. Afterwards, the video images were processed using the Ariel motion analysis system (APAS, USA).In the reference system used, a positive difference indicated that the heel was inverted relative to the shank, which implied a supinated position. Conversely, a negative difference indicated eversion and pronation, respectively.
Plantar Pressure Test: The Novel Pedar (Germany) pressure sensor system was used to collect the plantar pressure data during running. Only the plantar pressure of the right leg was collected, and the sample frequency was set at 100Hz. The subjects were asked to run on a treadmill at 3.3m/s for 2 minutes. Ten successful trials were subsequently used for data analysis.
Perceived Comfort Test: A questionnaire with visual analogue scale (VAS) was used to analyze the perceived comfort rating of running shoes. This method of assessing comfort has been proven to be reliable when used in this context (Clinghan *et al.*, 2008; Mundermann *et al.*, 2002). Nine questions were included in the questionnaire. The perceived comfort test was conducted on a normal running track (450m running at a comfortable speed). After each trial, the subjects were instructed to fill out the questionnaire. A 150mm-scale was adapted where the left-hand was labeled as “least comfortable imaginable,” and the opposite end as “most comfortable imaginable.” In the perceived comfort test, nine parameters were analyzed, namely, *question1*: Overall comfort (Q1), *question2*: Heel cushioning (Q2), *question3*: Forefoot cushioning (Q3), *question4*: Medial-lateral control (Q4), *question5*: Arch height (Q5), *question6*: Heel cup fitting (Q6), *question7*: Shoe heel width (Q7), *question8*: Shoe forefoot width (Q8), and *question9*: Shoe length (Q9).

Data analysis: APAS software was used in digitizing and analyzing the video images. To evaluate the rearfoot motion, four parameters were analyzed: rearfoot touchdown angle (TDR), rearfoot maximal pronation angle (RMP), total rearfoot motion (TRM), and peak angular velocity (PV).
In analyzing the plantar pressure, the insole was divided into nine areas. They were masked according to the human foot characteristics, namely, M1 (Medial heel), M2 (Lateral heel), M3 (Medial midfoot), M4 (Lateral midfoot), M5 (First metatarsal head), M6 (Second metatarsal head), M7 (Third, fourth, and fifth metatarsal head), M8 (Great toe), and M9 (Lesser toes) (Figure 1). Using the NOVEL PEDAR software, two parameters were provided (i.e., maximal force and peak pressure) in each area.

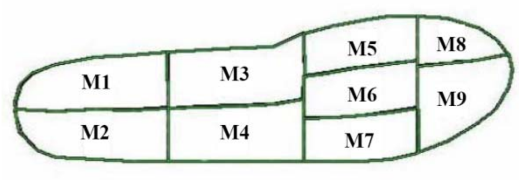

Figure1: Study masks

Statistical analysis: All data were presented as mean and standard deviation. A paired-samples T test was used to determine if the performance of the A shoes was different from that of the B shoes. Statistical significance was set at p<0.05.

RESULTS:

Rearfoot Movement Test: Results showed that among the four test items, only RMP exhibited significant difference between the shoes. The B-shoe (harder) has significantly greater angle than the A-shoe (soft). (Table 1)

Table 1: Parameters in the rearfoot motion testing

	TDR (degree)	RMP (degree)	TRM (degree)	MV (degree / s)
A-shoe	7.56 (2.83)	-6.40 (2.18)	12.86 (3.46)	-317.59 (92.51)
B-shoe	6.82 (2.80)	-5.30 (2.24) *	13.21 (3.26)	-305.00 (81.19)

Note. Values are mean (SD). *, Difference from A-shoe (P = 0.006).

Maximum Force: Statistical results showed that among the nine plantar areas, only one exhibited significant difference between the two shoes. The B-shoe showed a greater value than the A-shoe in area M4 at p=0.001. In M9, the B-shoe showed a trend of having greater value than the A-shoe (p=0.061). (Table 2)

Table 2：Values of maximal force (% body weight) for each area

	Total	M1	M2	M3	M4	M5	M6	M7	M8	M9
A-shoe	225.47 (23.49)	45.50 (9.15)	41.42 (7.56)	25.34 (5.88)	36.43 (6.17)	40.39 (13.26)	48.62 (8.14)	29.49 (4.76)	24.81 (5.43)	22.12 (6.96)
B-shoe	225.01 (26.57)	44.37 (11.36)	40.96 (9.49)	23.77 (6.97)	38.16 (5.50)*	41.15 (12.31)	47.42 (9.22)	28.32 (4.78)	25.29 (5.60)	23.36 (6.85)

Note. Values are mean (SD). *, Difference from A-shoe (P = 0.001).

Peak Pressure: There are two plantar areas which had significant differences between the shoes. These were M4 at p=0.001, and M9 at p=0.032. In both areas, the B-shoe exhibited greater values. (Table 3)

Table 3: Values of peak pressure (kPa) for each area

	Total	M1	M2	M3	M4	M5	M6	M7	M8	M9
A-shoe	326.65 (85.87)	180.78 (26.27)	182.63 (27.55)	122.78 (81.57)	129.97 (25.37)	281.37 (107.44)	274.77 (90.89)	196.78 (43.09)	265.80 (63.71)	131.12 (39.59)
B-shoe	335.42 (80.25)	190.38 (33.41)	192.07 (33.02)	128.37 (38.85)	142.78 (26.07)*	289.20 (101.59)	274.20 (91.57)	188.28 (44.79)	274.63 (57.99)	136.95 (38.55)*

Note. Values are mean (SD). *, Difference from A-shoe (P ≤ 0.05).

Perceived Comfort: Paired T-test showed that among the nine test items, only one *(question2*) showed significant difference between the two shoes. Notably, the A shoe had a higher score than the B shoe (p=0.035). (Figure 2)

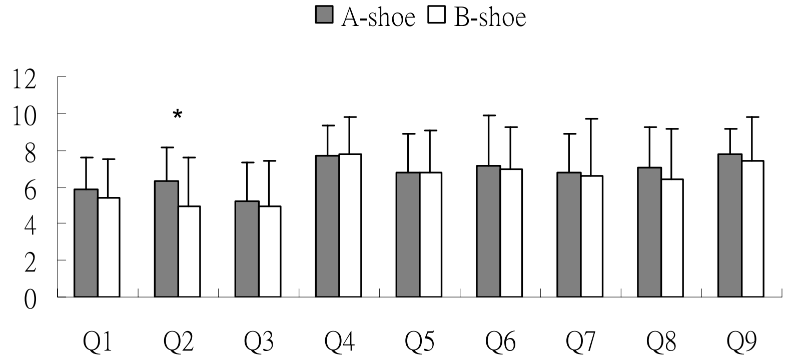

Figure 2: Comparison between the A-shoe and the B-shoe in perceived comfort test (*Difference from A-shoe, P ≤ 0.05)

DISCUSSION:

Previous studies have shown that shoes with a soft midsole have greater pronation values (Hamill et al., 1992; Kersting & Bruggemann, 2006; Wit BD., 1995). Our results on rearfoot motion are consistent with those of previous studies. Milani (1997) suggested that softer midsoles should be conductive to lower initial impact force, loading rate, and heel pressures but to higher pronation and pronation velocity as the feet accepts the weight of the body. Nigg (1987) suggested that a harder midsole component on the medial sides prevents the foot from further eversion. In the perception of impact, high correlation was observed between pressure and pronation (Milani et al., 1997). In our study, the significant difference of perceived comfort was only found in heel cushioning. This may be due to the fact that the shoe's midsole stiffness can be differentiated in the heel. The perceived comfort of the heel may be an important factor in sensory and neuromuscular systems at the adapted running style. Only a few studies were conducted regarding plantar pressure in shoes with different midsole hardness, in which individual pressure sensors were used in a specific position of the plantar foot (Kersting & Bruggemann, 2006; Milani et al., 1997). Using the Novel Pedar-X system to measure the plantar pressure, results of this present study showed that maximum force and peak pressure were not significantly different in the heel. However, greater force and pressure were found in the lateral side of the midfoot and forefoot in the harder midsole shoe. Smaller pronation may be the cause of this phenomenon. Although runners can adapt their running style to avoid high force and pressure in the heel when running in shoes with a harder midsole, force and pressure in the lateral area of the midfoot and forefoot, however, did not decrease.

CONCLUSION:

In this study, two prototype shoes with different midsole hardness were compared in terms of rearfoot motion, plantar pressure, and perceived comfort. The results showed that: 1) Perceived comfort of the heel is an important factor in sensory and neuromuscular system at the adapted running style; 2) Greater force and pressure are found in the lateral side of the midfoot and forefoot in harder midsole shoes; and 3) Smaller pronation may be the reason for the phenomenon described above.

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