CAN LABORATORY-BASED BIOMECHANICAL TEST RESULTS REFLECT THE PERCEIVED COMFORT DURING OVERGROUND RUNNING?

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The purpose of this study was to measure the relationship between laboratory-based biomechanical test results and the perceived comfort of subjects obtained from overground running. Twelve male runners were recruited (age=20.3 ± 0.8 years, weight=61.1 ± 5.1 kg, height=171 ± 4 cm). They participated in three tests: Heel Cushioning Test, Rearfoot Movement Test, and Perceived Comfort Test. Human pendulum device with a controlled impact velocity at 1.15m/s was used in the first test to measure the heel cushioning properties. A digital camera was located posterior to the treadmill to record the rearfoot movement in the second test. And a questionnaire that consisted of three questions was used to measure the percevied comfort after overground running. The correlations between variables of Heel Cushioning Test and Perceived Comfort Test ranged from low (r = 0.118) to mediate (r = -0.564), and the correlations between variables of Rearfoot Movement Test and Perceived Comfort Test ranged from low (r = 0.160) to mediate (r = -0.563). Peak force plays an important role in determining the comfort rating. Loading rate was negatively related to perceived comfort in heel cushioning. Total rearfoot motion was found to contribute most in perceived comfort in medio-lateral control.

KEY WORDS: force, cushioning, rearfoot, medio-lateral.

INTRODUCTION: In the past decades, many biomechanical tests were conducted to measure the protective functions of running shoes. Heel cushioning and rearfoot movement (medio-lateral control) are the two functions that have drawn most attention. It was believed that shoes with better heel cushioning or medio-lateral control would increase the perceived comfort of subjects. Although some studies showed the relationship between biomechanical test results and perceived comfort (Chen, Nigg, & de Koning, 1994; Jordan & Barlett, 1994), none of them relates the biomechanical test results to the perceived comfort obtained during overground running on running track.

Therefore, the purpose of the present study was to measure the relationship between biomechanical tests results (heel cushioning and medio-lateral control) obtained from laboratory tests and the perceived comfort of subjects obtained from overground running.

METHOD:

Subject: Twelve male runners were recruited (age=20.3 ± 0.8 years, weight=61.1 ± 5.1 kg, height=171 ± 4 cm). They were free from injuries and signed an informed consent form prior to participation. They were rearfoot strikers as determined previously by video filming at sagittal plan during treadmill running. All subjects had a shoe size about US 8 and were fitted with the running shoe (Gel-Kayano XI, Asics) that was the same size. We examined manually by palpation to ensure the shoe fitted the subjects.

Data Collection: All subjects participated in three tests within 6 weeks: Heel Cushioning Test, Rearfoot Movement Test, and Percevied Comfort Test.

Heel Cushioning Test. The human pendulum device invented by Lafortune and his colleagues (Lafortune & Lake, 1995) was used to quantify impact loads during running in this study. Subjects were instructed to lay on a lightweight bed with their right foots protruded over the bedding. By adjusting the distance to release the pendulum away from the force platform (9281CA, Kistler), subjects would hit the force platform with controlled impact velocity and the impact load at that impact velocity could be studied. The target impact velocity (1.15m/s) was monitored by a velocity transducer (DV301, Celesco). Only those trials with impact velocity within 1.12m/s – 1.19m/s were accepted (Lafortune & Lake, 1995). This velocity was chosen to emulate conditions similar to those observed during running at 3.6m/s (Cavanagh, Valiant, & Misevich, 1984). The force platform and velocity transducer were simultaneously sampled at 4000Hz by a computer.

Rearfoot Movement Test. A high speed video camera (9800, JVC) with sampling frequency of 200Hz was located posterior to the treadmill to record the rearfoot movement during running. Four markers were attached on the right side of the subjects (Figure 1). The first marker (M1) was placed below the gastrocnemius and the second marker (M2) was placed on the center of the Achilles tendon; the line connecting these two points was parallel to the axis of the lower leg. The third and the forth markers, M3 and M4 on the rear shoe represent the calcaneus. The definitions of rearfoot angles (supination, pronation, and neutral) were showed in Figure 2.

All subjects worn their own running shoes and ran at a speed of 3.3m/s for at least 20 minutes on the treadmill as warm up. They then changed into the testing shoe (Gel-Kayano XI, Asics) in the experiment. Video filming was started after 1min when the running speed was steady (3.8m/s). Ten footstrikes were filmed which would be processed by using APAS motion analysis system (USA).

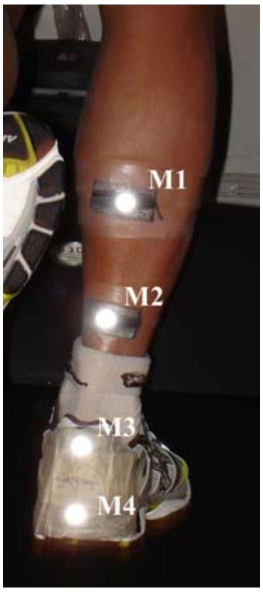

Figure 1: Four Markers were Attached on the Right Side of the Subjects. M1 and M2 Represent the Lower Leg; M3 and M4 Represent the Calcaneus

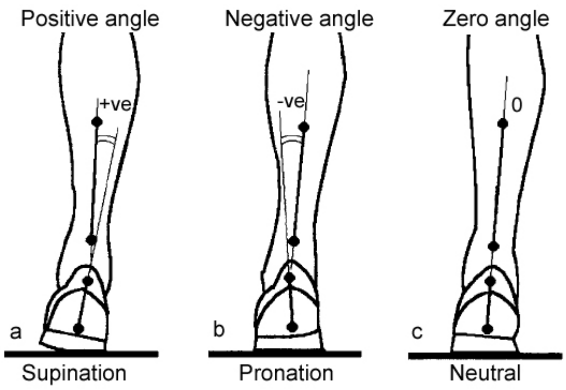

Figure 2: Rearfoot Angles of the Right Leg: (a) Positive Angle Indicates Supination, (b) Negative Angle Indicates Pronation, and (c) Zero Angle Indicates Neutral Position

Perceived Comfort Test. A questionnaire with visual analog scale (VAS) (Mundermann, Nigg, Stefanyshyn, & Humble 2002) was used to analyze the perceived comfort rating of the running shoes. Three questions were included in the questionnaire: (1) perceived overall comfort; (2) perceived comfort in heel cushioning; and (3) perceived comfort in medio-lateral control. In all questions, 0 mm represented “not comfortable at all” and 150 mm represented “most comfortable condition imaginable” as shown in Figure 3. The Perceived Comfort Test was conducted on a normal running track. Prior to the test, subjects were instucted to run with their own running shoe for 900 m at self-paced to warm up. They then ran 450 m at self-paced with the testing shoe (Mundermann et al., 2002) and the time for running was recorded. After the test, subjects were instructed to fill out the questionnaire.

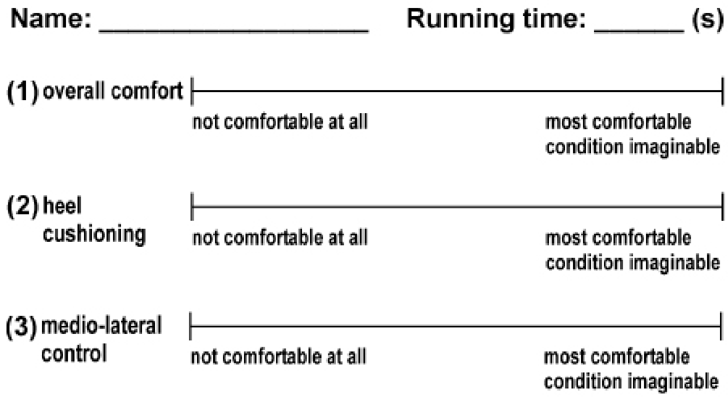

Figure 3: The Questionnaire Used in the Perceived Comfort Test

Data Analysis: Three parameters were collected in Heel Cushioning Test: time to peak force (TPF), peak force in terms of subject’s body weight (PF), and the loading rate (Load). Four parameters were collected in Rearfoot Movement Test: touch down rearfoot angle (TDRA), maximum rearfoot angle (MRA), total rearfoot motion (TRM), and peak angular velocity (PAV). Three parameters were collected in Perceived Comfort Test: perceived overall comfort (Comf), perceived comfort in heel cushioning (Heel), and perceived comfort in medio-lateral control (ML).

SPSS 12.0 was employed in the data analysis. The level of significance was set at 0.05. In both Heel Cushioning Test and Rearfoot Movement Test, results from the ten trials were averaged and Pearson Correlation was employed to examine: (a) the relationships between variables of Heel Cushioning Test and perceived comfort, and (b) the relationships between variables of Rearfoot Movement Test and perceived comfort.

RESULTS: In Heel Cushioning Test, the impact velocities of twelve subjects were within a narrow range (1.12 m/s – 1.19 m/s).The mean and standard deviation of impact velocity were 1.15 m/s and 0.02 m/s respectively. In Perceived Comfort Test, the mean and standard deviation of speed for 450 m running were, 3.27 m/s and 0.42 m/s respectively.

Table 1 Correlations between Biomechanical Variables and Perceived Comfort

	TPF (ms)	PF (BW)	Load (BW/s)	TDRA (Deg)	MRA (Deg)	TRM (Deg)	PAV (Deg/s)
Comf (mm)	0.118	-0.491	0.410	0.225	0.273	-0.325	0.243
Heel (mm)	0.346	-0.496	-0.564	-	-	-	-
ML (mm)	-	-	-	-0.441	0.383	-0.563	0.160

All correlations between biomechanical variables and perceived comfort during overground running were not significant ($P > 0.05$). The correlations between variables of Heel Cushioning Test and Perceived Comfort Test were low ($r = 0.118$) to mediate ($r = -0.564$), and correlations between variables of Rearfoot Movement Test and Perceived Comfort Test were also low ($r = 0.160$) to mediate ($r = -0.563$).

Table 2 Explained Variance (R^2) between Biomechanical Variables and Perceived Comfort

	TPF (ms)	PF (BW)	Load (BW/s)	TDRA (Deg)	MRA (Deg)	TRM (Deg)	PAV (Deg/s)
Comf (mm)	1.4%	24.1%	16.8%	5.1%	7.5%	10.6%	5.9%
Heel (mm)	12%	24.6%	31.8%	-	-	-	-
ML (mm)	-	-	-	19.4%	14.7%	31.7%	2.6%

DISCUSSION: All correlations between biomechanical variables and perceived comfort during overground running were not significant. Although the correlation was not significant, peak force play an important role in determining the comfort rating. The peak force was found to be negatively related to perceived overall comfort and perceived comfort in heel cushioning; it could explain 24.1% to 24.6% of the two comfort ratings.

It is interesting to note that loading rate was negatively related to perceived comfort in heel cushioning but positively correlated with perceived overall comfort. The negative relationship between loading rate and perceived comfort in heel cushioning is reasonable that the smaller the loading rate, the higher the cushioning ability of the running shoes thus leads to a better comfort rating in heel cushioning during running on field. However, the reason for the positive relationship of loading rate and perceived overall comfort was still unclear. In addition, perceived comfort in heel cushioning is believed to be one of the factors contributing to the perceived overall comfort, the contradicting result found here called for further investigation.
Among the four parameters in rearfoot movement test, total rearfoot motion was found to contribute the most in medio-lateral control (31.7%), followed by touch down rearfoot angle (19.4%), maximal rearfoot angle (14.7%) and peak angular velocity (2.6%). The order changed when perceived overall comfort was being considered: total rearfoot motion (10.6%), maximal rearfoot angle (7.5%), peak angular velocity (5.9%) and touch down rearfoot angle (5.1%). Total rearfoot motion was found to contribute the most in perceived comfort in medio-lateral control and perceived overall comfort.

CONCLUSION: Results of the present study showed that no single biomechanical variables have high correlation with perceived comfort ratings. It may be that (a) perceived comfort is affected by many factors that each of them contributes to the overall comfort at the same time; (b) subjects were not sensitive enough to differentiate each single factor and mixed them up to provide an overall feeling on one shoe.

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