CUSHIONING OF THE RUNNING SHOES AFTER LONG-TERM USE

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The purpose of this study was to investigate the cushioning properties of the running shoes after long running distance. Each of five subjects wore a new Nike air-shox shoe at the beginning and then at least ran thirty minutes on the same treadmill once or twice a week. The results of material test showed that impact force peaks significantly increased as the running distance increased. However, in the subject test, the tibial peak accelerations decreased as the running distance increased. It seemed to indicate that the subjects accommodate themselves to the material characteristics of the testing shoe by reducing the impact energies as heel strike. Based on the results, the cushioning abilities of the running shoes were attenuated after 300 km running distance. In the future, the change of the cushioning abilities of the running shoes should be monitored after more running distances.

KEYWORDS: ground reaction force, subjects test, material test, tibial acceleration.

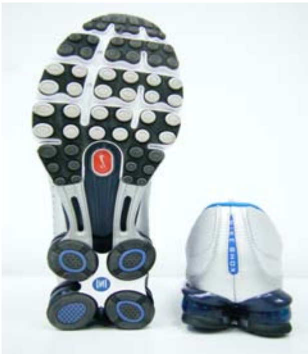
INTRODUCTION: Running and jogging are the most popular recreational activities in the world. However, the consecutive impact shocks due to foot strike may cause the chronic musculoskeletal injuries of lower limb. The cushioning properties of running shoes may play an important role to avoid running injuries. In previous studies, two methods were used to evaluate the cushioning properties of shoes: material test and subject test. The results of the two tests were conflicted in many studies (Kaelin et. al., 1985；Foti & Hamill, 1993；McNair and Marshall, 1994). The authors of these studies suggested that the material test is not valid to evaluate the situation of actual subject running. But in Chiu's study (2000), varying impact weight and impact height of the striker was used to test the cushioning of the shoe. The results showed that the curves of vertical GRF during the initial impact phase in subject test were similar to the results of material test. Chiu recommended that varying the impact energy in the material test to correspond with the impact energy of human running could evaluate the cushioning properties of running shoes validly.

Past studies concerned about the cushioning ability of running shoes after long distance running have showed that structural damage occurred in the foam of the midsole (Verdejo & Mills, 2004) and the shock absorbing ability would reduce (Schwanitz & Odenwald, 2008) after long distance running. Kinematics has been found to change to adapt shoe degradation during long distance running, especially in ankle joint movement (Kong et al., 2008). Furthermore, Lafortune and Hennig (1992) indicated that tibial axial acceleration was more sensitive at distinguishing the cushioning of different footwear than ground reaction force measurement. It has been shown that the impact acceleration and knee flexion angle would increase with fatigue (Verbitsky et al., 1998; Mizrahiet al., 2000). Therefore, in order to understand the interaction between the subject and shoe, the present study used both material test and subject test to investigate the change of cushioning abilities of the running shoes after a long running distance.

METHOD: Five recreational runners (Table 1) were recruited in this study. Before data collection each subject signed an informed consent, which was approved by the Human Experiment and Ethics Committee of National Cheng Kung University Hospital. Each subject wore a commercial running shoe (Nike, air shox 318684-142, US size 6.5-10.5) as shown in Figure 1a and finished a thirty minutes running session on the same treadmill (SportsArt 631) in the fitness gym nearby the laboratory once or twice a week. After each running session, each subject had to record the running time, distance and speed and return the testing shoe to the laboratory. All the testing shoes were preserved under humidity-controlled environment in the laboratory.

Table 1. The Characteristics of the Five Subjects

Subject	Shoe size (US)	Age (yrs)	Speed (km/hr)	Height (cm)	Weight (kg)	Gender
S1	6.5	21	10	161	52	Female
S2	10.5	24	10	178	70	Male
S3	9	29	8.5	171	61	Male
S4	9.5	25	10	180	70	Male
S5	8	24	10	165	62	Male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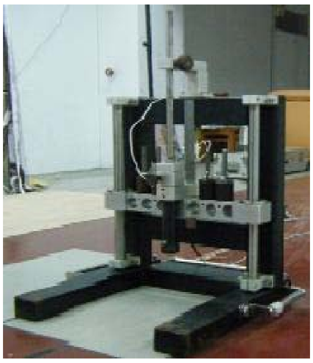
(b)

Figure 1. (a) The shoe tested in this study, and (b) the portable impact tester.

The portable impact testing equipment (see Figure 1b) was used to impact the running shoes on a force plate (AMTI BP400600). The impact testing with potential energy ranging from 0.61 to 6.08 J (equally distributed) was performed on the shoe after every 100 km running distance. The ground reaction forces were measured at a sample rate of 1000 Hz, and the signals were filtered using a 100Hz low-pass filter. Mean ground reaction force peaks were calculated from five impacts under each impact energy condition after omitting two extreme values.

The impact accelerations of the right tibial as heel strike were acquired during 30 minutes treadmill running after every 100 km running distance for each subject. A low-weight, three-axes accelerometer (dimensions: 33mm×28mm×19mm, weight: 17 grams, range: ±50g, sampling rate: 1000Hz) was attached to the tibial tuberosity of the right leg by elastic tape. The axial direction of the accelerometer was along the tibial longitudinal axis. Each subject was asked to run on a treadmill (MAC-7310, Tonic Fitness Technology, Inc, Taiwan) in the laboratory and increase the speed gradually until the same speed of the running session in two minutes.The acceleration data were acquired for 10 seconds at the 2^{nd}, 5^{th}, 10^{th}, 15^{th}, 20^{th}, 25^{th} and 30^{th} minute.

Two- way repeated measures ANOVA with the statistical software (SPSS, v17.0) was used to identify the effects of impact energies and running distance on the GRF peaks for material test and identify the effects of running time and running distance on the peak impact accelerations of the right tibial for subject test (α=0.05). For each subject, the peak impact accelerations were normalized by the mean peak acceleration of the 2^{nd} minute at 100 km running distance.

RESULTS: The mean time of finishing the running distances of 100, 200, 300km for the five subjects were presented in Table 2. The averaged 8 ~ 10 km running distance per week was similar to that of the general runners. The results of material test showed that the vertical GRF peak increased significantly as the impact energy increased ($p < 0.05$). The GRF peak also significantly increased as running distance increased ($p < 0.05$) (Table3). For subject test, there were no significant differences of the peak impact accelerations under different run distances and running time (Table 4).

Table 2. The Time (Mean ± S.D.) of Finishing the Running Distances of 100, 200 and 300km for the Five Subjects

variable	100 km (n=5)	200 km (n=5)	300 km (n=5)
time (weeks)	11.8±2.5	21.6±3.2	38.4±5.3

Table 3. The Vertical GRF Peaks (Mean ± S.D.) in Impact Testing (Unit：N)

Impact Energy (joule)	0 km (n=5)	100 km (n=5)	200 km (n=5)	300 km (n=5)
0.61	206.6±42.1	208.7±44.4	227.6±14.5	235.1±24.4
1.22	339.3±26.8	359.4±34.0	368.1±28.6	382.8±22.6
1.82	452.9±30.3	472.9±43.4	486.3±36.9	507.4±32.4
2.43	553.4±36.3	577.1±49.0	590.3±35.5	601.9±34.4
3.04	643.0±39.2	664.3±47.0	674.7±26.0	685.3±32.9
3.65	723.3±31.2	746.4±44.4	758.2±34.0	756.1±31.2
4.26	798.8±45.0	808.4±47.3	826.2±33.2	830.7±33.7
4.87	856.2±48.7	876.4±43.2	895.5±40.5	898.4±34.4
5.47	921.0±48.3	921.6±25.6	954.1±36.0	953.4±35.4
6.08	985.2±46.9	987.4±26.0	1016.2±31.6	1023.6±39.1

Table 4. The Normalized Peak Impact Accelerations (Mean ± S.D.) of the Right Tibial in Running Test

Running time (min)	100 km (n=5)	200 km (n=5)	300 km (n=5)
2	1.00±0.0	0.98±0.20	0.98±0.29
5	1.05±0.17	0.97±0.24	0.94±0.29
10	1.15±0.31	1.00±0.29	0.95±0.28
15	1.08±0.24	1.12±0.35	1.03±0.28
20	1.12±0.28	1.02±0.29	0.99±0.26
25	1.00±0.13	0.98±0.32	1.09±0.31
30	1.11±0.27	1.07±0.40	1.08±0.24

DISCUSSION: After 300 km running distance, the results of material test showed that impact force peaks increased significantly under different impact energy conditions. This indicated that the cushioning abilities of the running shoes were attenuated after long-term use. In previous studies concerned with the cushioning ability of the running shoes after long distance run, the running distance ranged from 500 to 750 km (Verdejo & Mills, 2004; Kong et al., 2008). The total running distance in this study was smaller than those of the past studies, the significant deterioration of cushioning ability of the running shoe should be detected after more running distance.

Although there were no statistical differences, the results of subject test showed that the peak accelerations decreased as the running distance increased. It seemed to indicate that the subjects accommodate themselves to the material characteristics of the testing shoe soles by reducing the impact energies as heel strike.

CONCLUSION: Based on the results of the material test, the cushioning ability of the running shoes significantly decreased after 300 km running distance. However, the peak impact accelerations of the tibia had a slightly reduction after 300 km running distance. The subjects seemed to adjust their landing strategies to reduce the impact energy responding to the attenuated cushioning abilities of the testing shoes. In the future, the change of the cushioning abilities of the running shoes should be monitored after more running distances.

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