USING IMPACT TESTING METHOD TO ESTIMATE THE ENERGY ABSORBED BY INSOLES IN SPORTS SHOES

Hung Ta Chiu
National Cheng Kung University, Tainan, Chinese Taipei

The purpose of this study was to estimate the energy absorbed by insoles in typical sports shoes with impact testing method. Three commercial sports shoe were used in this study. Totally eight impacts with 1.8 to 6.1 joules of potential energy were performed onto the heel region of the shoe. Peak acceleration of the striker was measured with accelerometer attached to the striker during impact. According to the linear regression equations between mean peak acceleration and impact energy for without and with insole conditions, the energy absorbed by insole under different impact energy (2~6 joule) was calculated. The new approach carried out in this study to calculate the energy absorbed by insoles could assess the role of insoles in the cushioning property of sports shoes.

KEY WORDS: Impact Tester, Cushioning, Peak Acceleration, Impact Energy

INTRODUCTION: Compared to a midsole, an insole has less shock attenuation ability because of its thinner thickness. It has been shown that interposing viscoelastic insoles in running shoes did not attenuate the vertical impact peak forces when running at 4 m/s (Nigg et al.,1988). However, in other subject tests, insoles were suggested to attenuate the impact shock comparing to barefoot (Chiu et al., 1998; Gillespie and Dickey, 2003) or the hard soled shoe conditions, such as a leather shoe or military boot (Windle et al., 1999; Folman et al., 2004).

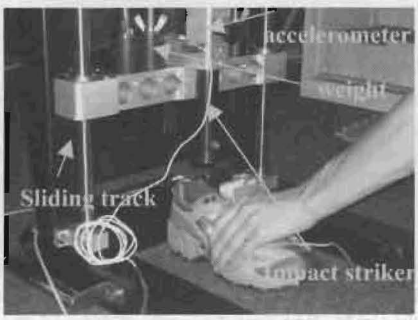
Impact testing method has been deemed to show the mechanical properties of the soles quickly and save the testing time, and has been suggested as a better method to test the functional properties of commercial shoes (Chiu & Shiang, 1999). Most of the previous studies that evaluated the cushioning properties of soles by impact testing used constant impact mass and drop height for different shoe conditions (Frederick et al., 1984; Henning & Lafortune, 1991; Henning et al., 1993; McNair&Marshall, 1994; Dixson et. al., 2002). However, the constant impact energy ($E = m \times g \times h$) cannot simulate the different responses subjects encounter in running. In Chiu's study (2000), various impact weights and drop heights of the striker were used to test the cushioning of the shoe. The results showed that increasing impact energy would cause larger impact loading. In addition, compared to subjects wearing the same running shoe, the curves of vertical GRF during the initial impact phase for running were similar to the results of impact testing. Chiu recommended that changing the impact energy into adequate region (3-7joule) in impact testing could evaluate the impact loading rate occurring as in actual running (at speed of 3 m/sec).

To date, no studies have attempted to measure the amount of energy absorbed by an insole during impact phase. Therefore, the purpose of this study was to estimate the energy absorbed by an insole in sports shoe with impact testing method.

METHODS: A portable impact tester was specially designed to impact the sports shoe with different impact energy. As shown in Figure 1a, this tester consisted of an impact striker to be released from different heights to impact the sole in the vertical direction. A low-weight accelerometer (range: ±500 g, sampling rate: 2000 Hz) was attached to the striker (weight: 6.2 kg) with an intense double-sided adhesive tape to measure the acceleration of the striker. Prior to impact testing trials, several impacts of the striker with the ground from different drop heights were done to justify that the accelerometer was rigidly attached to the striker.

Three commercial sports shoes were used in this study (see Figure1b). Shoe1 and shoe2 are running shoes and shoe3 is an indoor shoe for table-tennis activity in which the midsole is thinner than those in the running shoes. Shoe1, with well-cushioned material in midsole, was advertised as having better cushioning than shoe2 which only had single-density ethyl vinyl acetate (EVA) foam in it. Insole1 (the insole of shoe1) was composed of polyurethane foam with approximate thickness 4.6 mm in the heel. Insole2 (insole of shoe2) was made of latex

foam, and had approximate 3.4 mm thickness in the heel. Insole3 (insole of shoe3) was composed of EVA foam, and had approximate 4.2 mm thickness in the heel.
By varying the drop height of the striker, totally eight impacts with potential energy ranged from 1.82 to 6.08 joule (equally distributed) were performed onto the shoe. Two conditions, without and with an insole, were tested for each shoe. The striker was dropped to impact onto the heel region of the shoe and peak acceleration was measured at each impact trial. A power spectrum analysis of the acceleration signals showed that most of the signal's power has frequency below 600 Hz. Therefore, prior to analysis the acceleration data were filtered using a 600 Hz low-pass filter. Five trials were performed under each impact energy condition, and the mean peak acceleration was calculated from three data after omitting two extreme values. Consequently, the linear regression equation between mean peak acceleration and impact energy was calculated for each shoe condition. The same peak accelerations that occurred under with and without insole conditions indicated that they had the same cushioning effect. Therefore, the energy absorbed (ΔE between w/ and w/o insole conditions as having the same peak acceleration) by the insole defined in this study could be calculated from the regression equations.



(a)

(b)

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

Statistical effects of impact energy and shoe were tested with the statistical package SPSS using GLM (general linear method), factorial model, with a significant level $p<0.05$. Turkey's method of pairwise comparison was used to identify specific differences between energy levels and shoe conditions.

RESULTS AND DISCUSSION: The mean peak accelerations for each of the shoes without insole under different impact energies were shown in Figure1 (left). As impact energy increased, the peak acceleration significantly increased. It was significant that largest mean peak acceleration occurred for shoe3 and smallest for shoe1. As impact energy increased, the differences of peak accelerations between shoe conditions were significantly increased. These results indicated that the midsole of shoe1 did have better cushioning property than the other two shoes. The stiffer midsole of shoe2 and thinner midsole of shoe3 were considered to cause the larger peak accelerations, especially under high impact energy conditions.
The percentage reduction in peak acceleration for interposing insoles compared with no insole conditions were shown in Figure1 (right). Interposing insole attenuated the peak acceleration for all shoes. Insole3 had larger impact absorption (about 20-30%) than other two insoles. From the differences of linear regressions between without and with insole for three shoes (see Table 1), a trend has been demonstrated that the reduction of peak acceleration for insole1 decreased and the impact absorption for insole3 increased as impact energy increased. Insole1, interposed in well-cushioned shoe1, didn't perform the ability of impact shock attenuation for higher impact energies. However, insole3, interposed in bad-cushioned shoe3, did perform better impact absorption under high impact energy conditions. This seems to agree with the results of subject test in previous studies (Nigg et al.,1988; Windle et. al., 1999; Folman et.al., 2004).

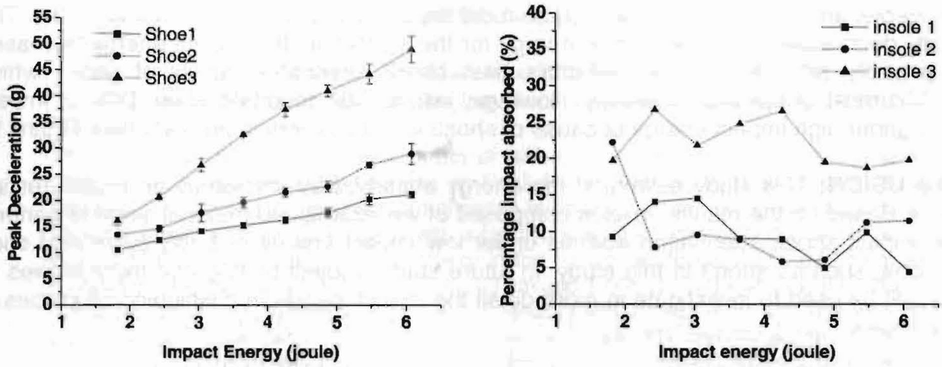


Figure 2 (1) Left figure - mean peak accelerations for shoes without insole under different impact energies. Statistical results: F(impact energy, A)=352.5, p<.05; F(Shoe, B)=1633.5, p<.05; and F(inter, A×B)=44.3, p<.05; (2) Right figure - percentage impact absorbed for insole compared to the shoe without insole.

Table 1 Linear regression equations between mean peak acceleration and impact energy under without and with insole for three shoes.

Shoe condition	without insole	with insole	Difference between w/ and w/o insole
Shoe1	$a = 2.44\times E + 6.32$ (r^2=0.99)	$a = 2.49\times E + 4.70$ (r^2=0.99)	$\Delta a = -0.05\times E + 1.61$
Shoe2	$a = 3.64\times E + 6.30$ (r^2=0.98)	$a = 3.44\times E + 5.00$ (r^2=0.99)	$\Delta a = 0.20\times E + 1.30$
Shoe3	$a = 7.72\times E + 2.94$ (r^2=0.99)	$a = 6.39\times E + 0.84$ (r^2=0.99)	$\Delta a = 1.33\times E + 0.84$

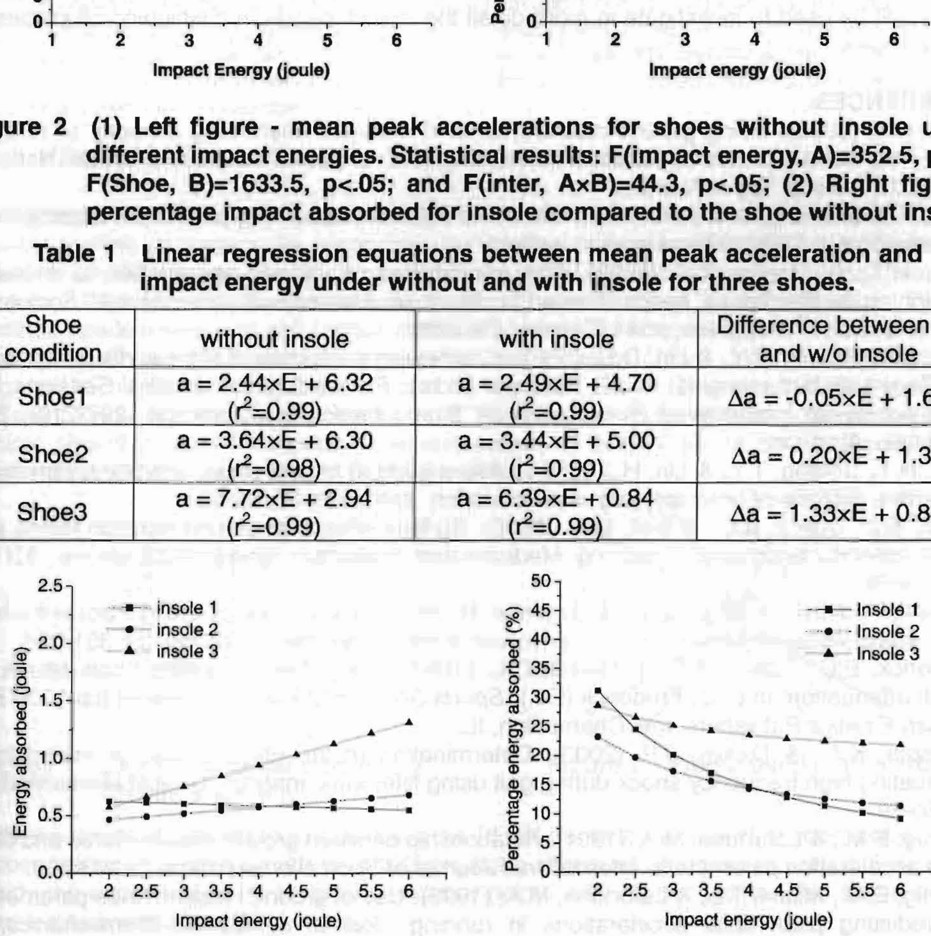


Figure 3 Energy absorbed by insoles (left figure) and percentage to impact energy (right figure).

Energy absorbed by the insoles under different impact energy (2~6 joule) was shown in Figure 2. Under low impact energy condition, the insoles could absorb greater ratio of impact energy than under high impact energy. This indicated insoles play an important role in the shock attenuation ability of sports shoes under low impact energy. As shown in Figure 2 (left), Insole1 and Insole3 absorbed more impact energy than insole2 under low impact energy condition. Although the difference was not apparent, it seemed that the polyurethane and EVA foam insoles had better cushioning properties than latex form. As the impact energy increased, the percentage of energy absorption by the insoles decreased because of the thin thickness of the insole, and the midsole would absorb more impact energy (Chiu and Cheng, 2004). The abruptly decreased ratio of absorbed energy for the insole1 as the impact energy increased was possibly attributed to the midsole's best shock attenuation ability of shoe1 which absorbed most of the impact energy. However, insole3 still absorbed about 25% of impact energy under high impact energy because of shoe3's bad cushioning property (see Figure 1).

CONCLUSION: This study estimated the energy absorbed by insoles by an impact testing method. Based on the results, insoles composed of well-cushioned material seem to perform better impact shock attenuation abilities under low impact energy or badly-cushioned shoe conditions, such as shoe3 in this study. In future study, subject testing and more insoles or shoes will be used to investigate in more detail the role of insoles in cushioning properties of sports shoes.

REFERENCES:

Chiu, H.T. (2000). Using ground reaction force to evaluate cushioning property of running shoe – the establishment of standard for material test. Unpublished doctoral thesis. National Normal University, Taipei,Taiwan.

Chiu, H.T., & Cheng, K.Y. (2004). The role of the insole in cushioning property of running shoe. *Proceedings of TSB2004* (publication in disk).

Chiu, H.T., & Shiang, T.Y. (1999). The comparison of various approaches to evaluate cushioning properties of sports shoes. In *Book of Abstracts of international Society of Biomechnics 17th Congress*, p544, Calgary, Canada.

Chiu, H.T., Shiang, T.Y., & Lin, D.C. (2001). Cushioning properties of shoe-surface interfaces in different impact energies. In J.R Blackwel (Eds.), *Proceedings of the Oral Sessions XIX Proceedings of International Symposium on Biomechanics in Sports* (pp. 207-210), San Francisco, America.

Chiu, H.T., Shiang, T.Y., & Lin, H.J. (1998). Attenuation of impact shock and plantar pressure of insoles, *Bulletin of university physical education. and sport,* 38, 53-59.

Dixon, S.J., Collop, A.C., & Batt, M.E. (2000). Surface effects on ground reaction forces and lower extremity kinematics in running. *Medicine and. Science in. Sports and Exercise.*, 32(11), 1919-1926.

Folman, Y., Wosk, J., Shabat, S., & Gepstein, R. (2004). Attenuation of spinal transient a heel strike using viscoelastic heel insoles: an in vivo study. *Preventive Medicine, 39*, 351-354.

Frederick, E.C.; Clarke, T.E., & Hamill, C.L. (1984). The effect of running shoe design on shock attenuation. In E. C. Frederick (Ed.), *Sports Shoes and Playing Surfaces* (pp.190-198), Human Kinetics Publishers, Inc. Champaign, IL.

Gillespie, K.A., & Dickey, J.P. (2003). Determination of the effectiveness of materials in attenuating high frequency shock during gait using filterbank analysis. *Clinical Biomechanics,* 18, 50-59.

Hennig, E.M., & Lafortune, M.A. (1991). Relationship between ground reaction force and tibial bone acceleration parameters. *International Journal.of Sport Biomechanics*, 7, 303-309.

Hennig, E.M., Milani, T.L., & Lafortune, M.A. (1993). Use of ground reaction force parameters in predicting peak tibial accelerations in running. *Journal of Applied Biomechanics*, 9, 306-314.

McNair, P.J., & Marshall, R.N. (1994). Kinematic and kinetic parameters associated with running in different shoes. *British J. Sports Medicine*, 28(4),256-260.

Nigg, B.M., Herzog, W., & Read, L.J. (1988). Effect of viscoelastic shoe insoles on vertical impact forces in heel-toe running. *American Journal of Sports Medicine*, 16, 70-78.

Windle, C.M., Gregory, S.M., & Dixon, S.J. (1999). The shock attenuation characteristics of four different insoles when worn in a military boot during running and marching. *Gait and Posture, 9*, 31-37.