

## CUSHIONING PROPERTIES OF SHOE-SURFACE INTERFACES IN DIFFERENT IMPACT ENERGIES

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The purpose of this study was to evaluate the cushioning properties of the various shoe-surface interfaces in different impact energies. Five shoe-surface conditions were tested in twelve different impact energies (3.19~6.67 joule). Results showed that higher impact energy increased the peak inertial force in each condition. Larger peak inertial forces were found in C1 (polyurethane only) and C5 (asphalt+shoe2) conditions. In low impact energy, the peak inertial forces were similar in C2 (polyurethane+shoe1), C3 (polyurethane+shoe2) and C4 (Asphalt+shoe1) conditions. The peak forces in C3 or C4 were larger than C2 in high impact energy. It was concluded that people ought to choose at least a well-cushioned shoe or surface when doing low impact energy activities, such as walking or jogging, and must choose both well-cushioned shoe and surface when doing high impact energy activities.

**KEY WORDS:** cushioning, shoe-surface interface, impact energy

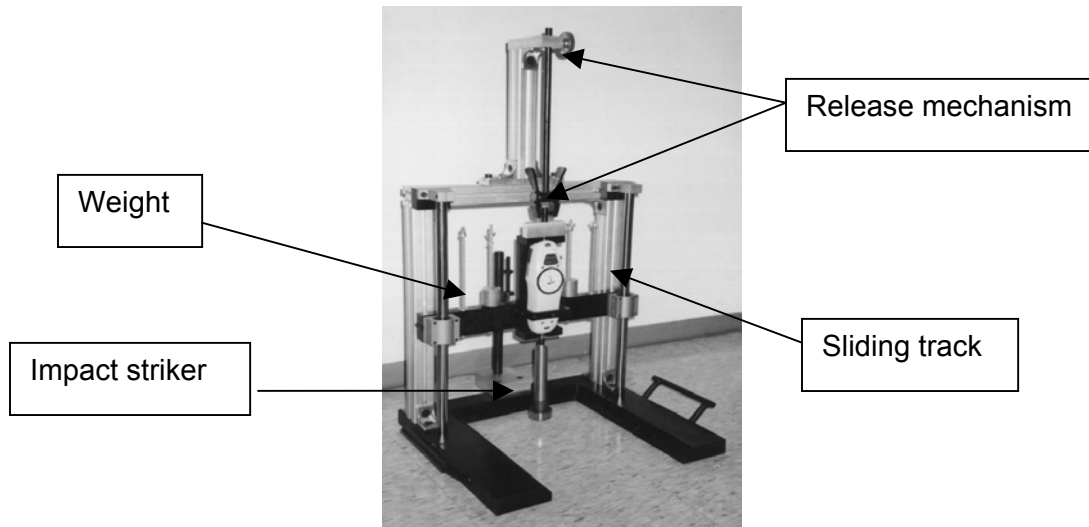
**INTRODUCTION:** Previous studies have shown that the impact forces occurring at heel strike result in injuries of bones (Nigg et. al., 1995). The shoe and surface have been assumed to play the major roles to reduce the impact loading. Many scientific studies investigated the influences of the properties of shoes on the impact force characteristics. Two methods were used to evaluate the cushioning properties of shoes: (1) material test – using impact test equipment and (2) subject test – evaluating subjects with force platform. Unfortunately, the results of the two tests were conflicted in most studies (Nigg et.al.,1983; Snel et.al.,1985; Foti & Hamill, 1993; McNair & Marshall, 1994). The authors of these studies assumed that material test was not a valid method to evaluate the cushioning properties of shoes.

Comparison with subject test, material test can show the mechanical properties of the soles quickly and save the testing time which is a better method to test the functional properties of the commercial shoes (Chiu & Shiang, 1999). The conflict between the two tests perhaps is connected with the constant impact energy used in material test that is different from the variability in subject test. In Chiu's (2000) study, various impact weight and impact height of the striker were used to test the cushioning of the shoe. The results showed that increasing impact energy would get larger impact loading. In addition, the curves of vertical GRF during the initial impact phase in subject test were similar to the results of material test. Chiu recommended that changing the impact energy into adequate region in material test could evaluate the impact force occurring as actual running. So far, less research has been undertaken on shoe-surface interaction characteristics. The purpose of this study is to evaluate the cushioning properties of various shoe-surface interfaces in different impact energies using material test. The results of this study will give a good suggestion for people to avoid running injuries.

**METHODS:** A portable shoe testing equipment was used to test shoes and surfaces in this study (see Fig1). This equipment was consisted of mechanical elements and easy to carry to do field test. The impact striker was hold with a metal clip that can control the impact height. Without any weight hanging on, the mass of the striker was 4.5kg. A low-weight accelerometer (range:  $\pm 50g$ , sampling rate: 1000Hz) was attached to the impact striker with elastic to measure deceleration of the striker.

As subject running, the impact energy ranged from 3 to 7 Joule (Chiu, 2000). Therefore, the four impact heights (5,6,7,8 cm) and three impact weights (6.5,7.5,8.5 kgw), total twelve impact energies (3.19~6.67 Joule), were chosen in this study to test the shoe-surface interfaces. The peak deceleration of the impact striker was recorded in each impact. Since the weight of the

impact striker was different in each impact condition, the peak inertial force (peak deceleration × striker's weight) was calculated to express the impact loading.



**Figure 1 - Portable shoe testing equipment. The mass of each weight is 0.25kg.**  
(Accelerometer attached to the impact striker with tape is not shown in this figure.)

The two testing shoes used in this study were commercial shoes (US size: 9). Shoe1 with well-cushioned material in midsole was announced had better cushioning than shoe2 which only has single-density EVA foam in it. Surely, shoe1 was more expensive than shoe2. Each of the testing shoes was placed on two surfaces – polyurethane and asphalt. The striker was then dropped to impact onto the heel region of the shoes. Table 1 shows the five shoe-surface conditions in this study. C1 is only testing polyurethane surface without shoe on it. Each shoe-surface condition should be tested in twelve impact energies. Each impact condition had five trials, and two extreme values were omitted.

**Table1 Five Shoe-Surface Conditions Chosen in this Study**

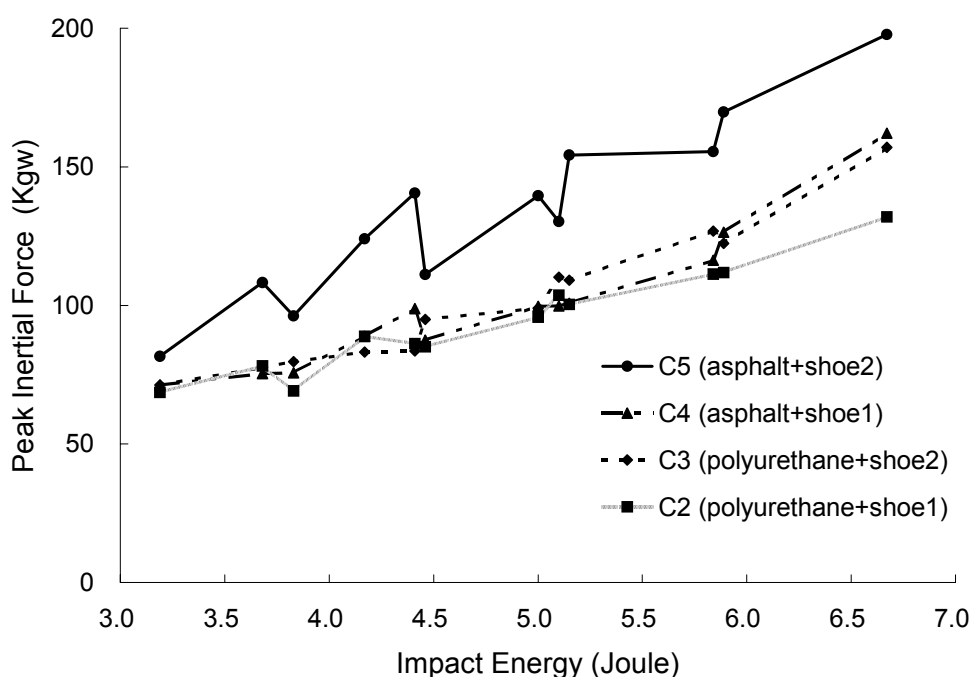
	C1	C2	C3	C4	C5
Surface	polyurethane	polyurethane	polyurethane	asphalt	asphalt
Shoe	w/o	shoe1	shoe2	shoe1	shoe2

**Table2 The Inertial Force Peaks (kgw) for Five Shoe-Surface Conditions in Low and High Impact Energies**

Impact energy	C1	C2	C3	C4	C5
Low (3.19 J)	328.1 (8.6)	68.6 (1.4)	71.2 (1.5)	71.3 (4.6)	81.6 (6.9)
High (6.67 J)	462.3 (0.6)	132.0 (3.7)	157.0 (9.2)	162.2 (6.6)	197.8 (2.8)

**RESULTS AND DISCUSSION:** Table 2 presents the peak inertial force for five shoe-surface conditions in low and high impact energy. As expected, each shoe-surface condition showed larger peak inertial force in high impact energy. The peaks in C1 were much larger than other conditions in two different impact energies. Shoes seemed to be able to provide the better cushioning as surface could not reduce the peak inertial force. Among other four shoe-surface conditions, the C5 had larger peak force than others (C2, C3 and C4) in each impact energy. And in low energy, the peak inertial forces were similar in C2, C3 and C4. However, the peak in C3 or C4 was larger than C2 for high impact energy. These results give an indication that either one of shoe and surface is well cushioned which can provide enough cushioning effect for low

impact energy activities. In high impact energy, both shoe and surface are very important for the cushioning of the interface. In application, we recommend that wearing shoes is very important for running on polyurethane surface, although polyurethane is a well-cushioned material. And people maybe ought to select at least one well-cushioned shoe (such as shoe1 in this study) or surface (polyurethane) when walking or jogging (low impact energy activities) and select both well-cushioned shoe and surface when high speed running (high impact energy activities). As already mentioned, the peak inertial forces in C3 or C4 were larger than C2 for high impact energy (6.67 J). However, they were similar for low impact energy (3.19 J). The critical energy to result in the differences among the conditions is not clear. Fig2 shows the influence of the impact energy on the peak inertial force. Clearly, as the impact energy less than about 5 joule, the peak inertial forces were similar in C2, C3 and C4. However, as the impact energy increased and larger than about 5 joule, the peaks of C3 and C4 were larger than C2. This result gives an important suggestion for the runners to select the shoe and surface appropriately and safely during walking or running.



**Figure 2 - The influence of impact energy on peak inertial forces in four shoe-surface conditions.**

**CONCLUSION:** The material test has been assumed a valid method to evaluate the impact loading as actual running. In this study, different impact energies were used to evaluate the cushioning properties of the shoe-surface interfaces and some surprising information was found. As a conclusion, we recommend that people ought to choose at least a well-cushioned shoe or surface when doing low impact energy activities, such as walking or jogging, and must choose both well-cushioned shoe and surface when doing high impact energy activities.

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