COMPARISON OF SHOCK ATTENUATION BETWEEN SPORT SHOES WHEN LANDING FROM VERTICAL JUMP

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Many sports require participants to perform jump landing. However, the peak impact force at landing was about 7.1 body weight, which might lead to injury. Basketball shoe, running shoe, cloth sport shoe, and barefoot were selected in the present study. The purpose of this study was to investigate the impact when landing from vertical jump. Eleven subjects with no reported lower limb injuries were recruited. After warm-up session, each subject performed 12 jumps. The sport shoes were assigned to subjects randomly. In ANOVA analysis, significant difference only existed in time to first impact peak force, $F=8.99$, $p=.001$. The results showed that muscles of ankle joint (0.0688s) could not react to first impact peak force (0.0174s). Same as previous studies, results were affected by subjects' perception. In conclusion basketball and running shoes provided better shock attenuation in rearfoot.

KEY WORDS: sport shoe, shock, attenuation, impact, landing, vertical jump.

INTRODUCTION: Many sports require participants to jump, like rebound in basketball, spike in volleyball, heading in soccer and rope skipping. However, the average impact force during landing phase was reported as between 4.1 times and 6 times body weight, and the peak reaching 7.1 times body weight (McClay et al., 1994; Valiant & Cavanagh, 1983). It is suspected that excessive and repetitive impact forces exerted on the feet may harm the body and may lead to acute or chronic injuries. Therefore, the protective functions of sport shoes have been investigated by scientists.

Basketball shoe, running shoe, cloth sport shoe, and barefoot were selected in the present study. Cloth sport shoe, a kind of traditional and low-price sport shoe has become popular in Hong Kong and the People's Republic of China. The cloth sport shoe is composed of thin cloth (about 2mm), and has a thin base (about 13mm). Although it is popular in Hong Kong and the People's Republic of China, research on the shock attenuation of cloth sport shoe is limited (Fong, Hong, Lamontagne, & Li, 2002). The purpose of study was to investigate the impact in forefoot and rearfoot when landing from a vertical jump. Three sport shoes (basketball shoe, cloth sport shoe and running shoe) and barefoot were selected. The study recruited human subjects in order to better simulate the situation when the sport shoes were actually worn by participants.

METHODS: Eleven female PE undergraduate students were recruited as subjects. The mean age, mass, and body height were 21.18, 52.99kg and 1.62m respectively. They were all with no reported lower limb injuries and wore experimental shoes comfortably. Written informed consent form and physical activity readiness questionnaire (PAR-Q) were obtained from subjects before any testing.

One force platform (Kistler 9281CA) set at 1000 Hz sampling frequency was mounted on the mounting frame which was fixed on the ground. A yardstick was located in front of the force platform. The yardstick was composed of a vertical stainless steel tube and 50 horizontal plastic sticks, with 1cm precision. A digital camera (JVC 9800) set at 100 Hz sampling frequency was located in front of the force platform to ensure forefoot landing and the landing time between left and right feet were within 10ms.

Warm up session: Five barefoot practice trials were performed to familiarize subjects with the test procedure. In each trial, subjects performed countermovement vertical jump, where left foot landed on wooden platform and right foot on force platform (Brizuela, Llana, Ferrandis, & Garcia-Belenguer, 1997; Valiant & Cavanagh, 1983). During jumping, subjects were asked to uphold their hands to facilitate symmetry landing, and touched the horizontal bar of the yardstick simultaneously with their fingertips of both hands (Gross & Nelson, 1988). The two-hand-up jumping was used to aid symmetric landing and equalized effort across subjects.

The landing included forefoot contact and then heel contact. Knee flexion was allowed.
Pre-test session: Three trials were used to record subjects' maximum vertical jump height. Thirty seconds rest between jumps was allowed to avoid fatigue.
Test session: Subjects were required to jump at 90% of the maximum jump height recorded in the pre-test session (Gross & Nelson, 1988). Barefoot, basketball shoe, cloth sport shoe and running shoe were assigned to subjects in a randomized sequence. In each condition, total of 12 trials were conducted. The trials were divided into three series, and each series contained four trials. Rest periods of 30 seconds between series and of 10 seconds between jumps were allowed to avoid fatigue. Asymmetric landings, classified as contact with one foot earlier than 10ms prior to the second foot contact, were confirmed by viewing the video recorded by digital camera. All asymmetric landings were discarded in the data process.

RESULTS AND DISCUSSION: First impact peak represented the peak force during forefoot landing. The time to first impact peak force represented the time interval from the initial forefoot contact with the ground to the first impact peak force occurrence. First loading rate represented how many force was exerted on the forefoot region per second. Second impact peak represented the peak force during rearfoot landing. The time to second impact peak force represented the interval from the initial forefoot contact with the ground to the second impact peak force. Second loading rate represented how many force was exerted on the rearfoot region per second. The mean values of these parameters were showed in Table 1.
In ANOVA analysis, significant difference only existed in time to first impact peak force, $F=8.99$, $p=.001$. When further analyzed the differences between sport shoes in terms of time to first impact peak force, significant differences existed between barefoot and basketball shoe ($p=.001$), barefoot and running shoe ($p=.018$), cloth sport shoe and basketball shoe ($p=.035$).

Table 1 Mean value of the 6 parameters measured in the study.

Parameters	Barefoot	Basketball Shoe	Cloth Sport Shoe	Running Shoe
First impact peak force (BW)	0.69	0.63	0.67	0.71
Time to first impact peak force (s)	0.0218	0.0132	0.0180	0.0166
First loading rate (BW/s)	37.6	57	39.5	41.6
Second impact peak force (BW)	1.56	1.36	1.44	1.44
Time to second impact peak force (s)	0.0962	0.0942	0.0915	0.0940
Second loading rate (BW/s)	17.6	14.9	16.5	15.7

The average time to first impact peak force in the present study was about 0.0174s, and the average time to second impact peak force was about 0.0940s. However, the reflex time of ankle joint muscles (peroneus brevis and peroneus longus) was about 0.0688s as showed by Karlsson and his colleagues (Karlsson, Peterson, Andreasson, & Hogfors, 1992). This clearly means that ankle joint muscles can only react to the second peak force but not the first peak force. Too large impact force occurs before the ankle joint muscles can react to the force would lead to acute or chronic injuries.
The smaller loading rate in barefoot and cloth sport shoe in the present study may be explained by the perception of the subjects. Lake and Lafortune (Lake & A., 1998) used human pendulum apparatus to simulate the impact encountered during running and they found that subjects' perceived magnitude of impact loading was highly correlated ($p=0.831$) to the mechanical inputs that were measured. Moreover, Gross and Nelson (Gross & Nelson, 1988) investigated the shock attenuation during jump landing. They also found that subjects were awared of the surface they were landing on and have proprioceptively adjusted their landing. In the present study, when a severe impact in the coming landing was perceived by the subjects, they might alter their landing movement to attenuate the shock. Further method should be invented to eliminate or diminish the perception factor.

One limitation in the present study was the 90% jump height. The height was set to facilitate more consistent performance and to avoid fatigue. However, this jump height might not be high enough to differentiate the shock attenuation ability of different sport shoes. It was thought that increasing the jump height would better differentiate the shock attenuation ability among sport shoes. Further study was needed to provide information in this aspect.

CONCLUSION: Same as previous studies (Gross & Nelson, 1988; Lake & A., 1998), the results of present study were also affected by the perception of the subjects. However, some information could be extracted from the results. Lower second impact peak force and second loading rate in basketball shoe and running shoe provided evidence that these shoes attenuated shock during rearfoot landing. As the second impact peak force was almost twice the first impact peak force, shock attenuation at rearfoot region was more important. Nevertheless, shock attenuation at forefoot region should not be neglected as the muscles of ankle joint cannot react to this rapid shock and the protection is mainly relied on the sport shoes.

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