IN VIVO ASSESSMENT OF THE SHOCK ABSORPTION CHARACTERISTICS OF ATHLETIC FOOTWEAR INSERT MATERIALS

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INTRODUCTION

Standard procedures have been developed to test the performance of different shock absorbing midsole materials for footwear using mechanical impacter devices (ASTM, 1995). Material properties are determined using a specific impacting mass and velocity, however, these procedures neglect the material’s interaction with the body in moderating the shock to its structures. This investigation examined relative material performance while subjects wore athletic footwear for three controlled impact velocities of a human pendulum apparatus.

REVIEW AND THEORY

Previous studies assessing the shock absorbing performance of athletic footwear during overground running have shown few significant differences in impact forces for shoes of differing midsole hardness. More recently a human pendulum approach has been used to assess the cushioning performance of footwear under controlled initial lower limb kinematics, for which midsole cushioning differences were shown for one impact velocity (Lawless and Lafortune, 1995). However, materials used in athletic footwear exhibit visco-elastic properties and therefore their shock absorbing properties are load rate dependent. Greater load rates may affect the relative shock absorbing performance of insert materials, necessitating their assessment over a range of controlled impact velocities. Also, few studies have assessed cushioning insert materials by systematically incorporating them into a shoe midsole. The purpose of this study was to assess the relative in vivo shock absorbing performance of seven insert materials incorporated into a shoe for a range of three controlled impact velocities.

PROCEDURES

Eight male subjects (mean age 28.8 yr., mass 70.8 kg, and height 1.70 m) experienced impacts to the right heel using a human pendulum apparatus (Lafortune and Lake, 1995). Subjects wore experimental athletic shoes with seven insert materials (M1-M7) alternately positioned into a hole (40 × 70 × 10 mm) cut into the heel. Subjects wore the same insole and sports socks. Ten to eleven consecutive impacts per insert material were administered for 3 impact velocities, 0.85 m s\(^{-1}\) (V1), 0.95 m s\(^{-1}\) (V2) and 1.05 m s\(^{-1}\) (V3). Insert materials and impact velocities were randomised for each subject. Subjects maintained their knee in full extension during impacts, with the foot slightly dorsiflexed to ensure a heel first contact. External impact force (WRF) was measured by a wall-mounted force platform. Tibial shock (TS) was measured by a skin-mounted accelerometer attached to the anterior medial aspect of the tibia, 10 cm proximal to the medial malleolus. Head shock (HS) was measured by a bite bar mounted accelerometer. Force and shock signals were sampled at 1000 Hz and low pass filtered at 60 Hz and then high pass filtered at 8 Hz prior to spectral analysis. Impact severity was characterised by peaks, time to peaks and mean power frequency (MnPF) of WRF, TS, HS. A two-way repeated measures ANOVA was applied to each impact variable (\(\alpha = 0.05\)).
RESULTS AND DISCUSSION

Figure 1: Relative performance of materials M1-M7 for WRF and TS for V1, V2 and V3.

All impact variables examined showed significant main effects (p < 0.05) for both materials and impact velocity, except WRF and HS MnPF’s, which were significant for the materials only. Across the range of loads experienced by the subjects (~1.7-2.3 BW’s) the seven materials showed consistent relative shock absorbing performance for the 3 impact velocities (Figure 1). The WRF load rate (LR) interaction was very similar to that of tibial shock. The relative difference in performance of inserts M4 and M5 for the time domain variables was 5-26%, while for the frequency domain variables it was 5-14% for V1. Based on extreme material differences the present data suggests LR and TS best differentiate between insert materials’ shock absorbing performance for the range of impact velocities tested. Lawless and Lafortune (1995) also reported the former as superior in differentiating between footwear midsole cushioning. Time domain variables were most sensitive, particularly LR, to changes in impact velocity. The frequency domain variables showed a lack of sensitivity to velocity changes, although they tended to increase with velocity, but clearly they are more dependent on material properties rather than velocity. For most of the materials examined the majority of the impact variables (WRF, LR, TS, HS and TS MnPF) demonstrated an approximately linear increase with velocity for the group. Interestingly, however, some subjects showed non-linear tendencies for WRF, LR and TS. These individual trends need further investigation across a greater range of impact velocities to confirm whether group trends are still approximately linear. In conclusion, for the present in vivo testing procedure the particular range of impact velocities did not alter the relative shock absorbing performance of the insert materials tested.

REFERENCES
Lawless and Lafortune Proc. 2nd ISB Footwear Symposium, 8-9, Cologne, 1995.

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