RELATIONSHIP BETWEEN MECHANICAL, BIOMECHANICAL AND PERCEPTUAL PARAMETERS OF CUSHIONING PROPERTIES IN RUNNING SHOES

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INTRODUCTION

Cushioning is one aspect of running shoe research and development. Inadequate running shoe cushioning may lead to overuse injuries. There are several innovative cushioning designs in running shoes available, e.g. Nike Shox™, Asics Gel, Adiprene. Damping elements made of different materials and geometries are placed in or completely replace the midsole of running shoes. These concepts should be tested by a comprehensive approach including mechanical, biomechanical and perceptual testing (Milani and Hennig, 2002). The purpose of this study was to analyze the relationship between these testing approaches for rearfoot cushioning of an innovative running shoe design.

METHODS AND PROCEDURES

The innovative running shoe design used in this study allowed modifying rearfoot hardness by interchangeable TPU units. These units had a shore hardness of 75A, 80A, 85A and 90A. A commercially available traditional cushioning running shoe served as a reference shoe (TRS). Mechanical testing was performed by vertical application of a loading profile according to force-time characteristics of a heel-to-toe specific running speed of 3.5 ms⁻¹ (Cavanagh and Lafortune, 1980). Maximum deformation [mm] and stiffness [N/mm] were measured. For biomechanical and perceptual testing 20 male subjects (25.6yrs +/- 4.6; 177.0cm +/- 5.1; 71.0kg +/- 6.1) were recruited. During biomechanical testing running speed was set to 3.5 ms⁻¹ (+/- 0.1). Five repetitive heel strike running trials across a Kistler force platform (9287BA) were recorded. Simultaneously, tibial acceleration was measured by a lightweight accelerometer (EGAX-F-100). Shoes were tested in randomized order. For perceptual testing, subjects ran at individual self-selected running speed on an indoor track. Perceptual ratings were obtained while running in each shoe condition for 200m. The intensity of heel impact was rated using a 9-point category estimation scale (1: much lower to 5: equal to 9: much higher) compared to a reference. The shoe condition with medium hardness according to mechanical testing results was used as the reference shoe and was set to be 5 on the rating scale. Subjects performed one 200m lap wearing the reference shoe prior to testing each of the remaining shoe conditions. For data evaluation mean values of left and right shoes for mechanical testing and mean values of the five repetitive trials for biomechanical testing were calculated. For statistical analysis a repeated measures ANOVA and Post-Hoc comparisons according to Fisher’s LSD were used. Additionally, correlation analyses between parameters of the three testing areas were performed.

RESULTS

Mechanical testing shows less deformation (75A=9.5mm to 90A=7.4mm) and higher stiffness (Figure 1) for harder shoes. The TRS
shows higher deformation (12.8mm) and lower stiffness than the innovative shoe design.

**Figure 1: Mechanical stiffness**

Results for biomechanical testing show no differences between shoe 75A, 80A, 85A and 90A in force rising rate (69.4 - 71.3N/(bw*s)) and tibial acceleration (Figure 2). The TRS shows significant lower tibial acceleration (p < 0.01) and force rising rate.

**Figure 2: Tibial acceleration**

In perceptual testing subjects rated the softest and the hardest shoe condition of the innovative shoe design according to mechanical stiffness values (Figure 3).

**Figure 3: Rearfoot hardness – intensity rating**

For the two different shoe concepts, statistical analyses result in high correlation between mechanical and biomechanical parameters (e.g. deformation and tibial acceleration: r = 0.91; p < 0.05), but within the innovative shoes no correlation is present (r = 0.13; p = 0.87). No relationship was found between mechanical and perceptual parameters or perceptual and biomechanical parameters.

**DISCUSSION**

In mechanical testing differences between all shoe conditions are present. The results in the biomechanical test show significant differences between both running shoe concepts, but - surprisingly - no differences within the shoes of the innovative running shoe concept. This may indicate that differences are too small to influence running biomechanics. Otherwise, in perceptual testing subjects identified the softest and the hardest shoe condition according to mechanical testing results. Adaptation behaviour may be the reason for this result (Hennig et al., 1996). Subjects may have perceived differences between shoe conditions and adapted the running style to avoid high heel impacts.

**SUMMARY**

It was shown that differences in midsole hardness between and within two running shoe concepts can be measured mechanically. These differences do not necessarily need to be detected during biomechanical testing. This is most likely due to movement adaptation of runners. During perceptual testing subjects perceived differences of rearfoot hardness within the innovative shoe conditions. Further investigations would be desirable to evaluate the movement adaptation. Foot strike angle in the sagittal plane may be a parameter of interest.

**REFERENCES**


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