THE ROLE OF SHOE SOLE DUROMETER ON JUMPING KINETICS

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This study investigated the relationship between shoe heel density (HD), toe density (TD) and its effect on the peak ground reaction force (GRF) and rate of force development (RFD) during jumping. This study also assessed the reliability of the durometer to assess shoe soles. Subjects included 12 men. Shoe HD and TD were assessed via durometer and kinetics were determined during the countermovement jump on a force platform. A Pearson bivariate correlation analysis was performed. Results reveal that HD was not correlated with GRF (r = -.22, p = .50) or RFD (r = -.14, p = .67). Similarly, TD was not correlated with GRF (r = -.29, p = .37) or RFD (r = -.28, p = .37). Intraclass correlation coefficients for the heel and toe durometer were .95 and .92, respectively. Jumping kinetics were not mediated by shoe sole characteristics, though the durometer was reliable for assessing shoe soles.

KEYWORDS: ground reaction force, heel, toe, countermovement jump.

INTRODUCTION: Shoes may create an advantage in athletics. For example, insoles and shoe modifications have been used to enhance athletic performance. These modifications were assessed during sprinting, cutting, and jumping. Shoe properties have been assessed through the use of a durometer. More specifically, durometers have been used to measure the density of the heel and midsole regions of the shoe, along with the density of additional shoe modifications.

Adding carbon fiber insoles is the most common shoe modification (Gregory et al., 2018; Selish et al., 2015; Stefanyshyn & Nigg, 2000; Stefanyshyn & Fusco, 2016; Stefanyshyn & Wannop, 2016). The addition of the carbon fiber insoles increases stiffness, without any permanent modifications to the shoe. Another modification that has been tested is the inclusion of elastic bands to the forefront of the shoe, allowing for more flexibility in the shoe (Chen et al., 2014). Other shoe modifications that have been assessed include changes made by the manufacturer to the shoe itself. One example of this is the impregnation of thermoplastic polyurethane in between the midsole and outsole of the shoe (Tinoco et al., 2010).

Shoe modifications have been tested during a variety of activities, with the most common being sprinting, jumping, and cutting. Increasing the stiffness of shoes has been shown to improve sprinting times. On average, sprinters decreased their 10-yard sprint time by 1.2 percent with the addition of carbon fiber insoles (Gregory et al., 2018). Additionally, the stiffness of shoe soles has been linked to an increase in jump height, while also decreasing the effects of fatigue on the user. A 2.5 percent increase in vertical jump height was shown with the addition of a carbon fiber insole (Gregory et al., 2018). Increased shoe sole stiffness has also been shown to decrease performance times in multi-directional sprints and cutting movements by up to 1.4 percent (Tinoco et al., 2010).

In addition to research assessing modifications to shoes, two studies have used durometers to assess the properties of shoe soles. Durometers were used to assess the density of heel cushioning and how this property changes as the shoe ages (Cornwall & McPoil, 2017). A durometer was also used to assess the composition of the midsole, for the purpose of determining if the density of the midsole effected factors such as the ankle eversion angle (MacLean et al., 2009). However, no study has used a durometer to assess the ball and heel regions of the shoe or to assess the role of shoe sole density on jumping performance. Additionally, no study has assessed or published data regarding the reliability of using durometers to assess shoe sole characteristics.

The countermovement jump (CMJ) requires the production of substantial ground reaction forces (GRF) with a high rate of force development (RFD). During the CMJ, compressive forces are transmitted through the shoe sole into the ground, and the nature of the shoe sole may affect jump kinetics. The potential relationship between shoe sole density and the kinetics of the CMJ is not known. The purpose of this study was to investigate the relationship between heel sole density, toe sole density, and the GRF and RFD during the CMJ. This study also sought to assess the reliability of using a durometer to assess shoe soles.

METHODS: Twelve men (mean ± SD; age = 23.5 ± 3.9 years) volunteered for this study and provided informed consent. This study was approved by the Institutional Review Board. Additional subject information is shown in Table 1.

Subjects participated in a standardized warm-up including a general, dynamic, and activity specific warm-up, and were taught correct performance of the CMJ. The general warm-up consisted of a low intensity, three-minute cycling on an ergometer. The dynamic warm-up included five slow bodyweight squats, ten yards of walking lunges, backwards walking lunges, walking hamstring stretches, and a walking quadriceps stretch, along with a twenty-yard skip. The activity specific warm-up included five self-perceived CMJ of increasing intensity. During the activity specific warmup, subjects received instruction and feedback about the correct CMJ form.

Subject heel sole density (HD) and toe sole density (TD) were assessed via durometer (Model 52-50546, Longacre, Booneville, IN, USA). Subjects wore the basketball or tennis shoe of their choice, resulting in shoe heel and toe durometer differences of 20.97% and 22.59%, respectively, across all of the subject's shoes. Subject's shoes included manufacturer's insoles and no aftermarket orthotic devices. Durometer values were obtained consistent with previously published methods (Cornwall & McPoil, 2017).

Subjects then performed two countermovement jumps, with fifteen second rest in between each repetition. The test exercises were performed on a force platform (BP 6001200, Advanced Mechanical Technologies Incorporated, Watertown, MA, USA), which was countersunk and mounted flush to the floor The force platform was calibrated prior to the testing session. Data were acquired at 1000 Hz and analyzed in real time with proprietary software (BP 6001200, Advanced Mechanical Technologies Incorporated, Watertown, MA, USA). The peak GRF and RFD were obtained from the take-off phases of the force-time record for each of the CMJ. These data were obtained and reduced based on previously published methods (Jensen & Ebben, 2007).

A Pearson's bivariate correlation analysis was performed using a statistical software (SPSS 26.0, International Business Machines Corporation, Armonk, New York) to determine relationship between HD, TD, GRF, and RFD. The trial-to-trial reliability of each dependent variable was assessed using average measures Intraclass correlation coefficients (ICC) and a repeated measures analysis of variance. Coefficients of variation were also calculated. The *a priori* alpha level was set at $p \leq 0.05$.

Table 1. Subject descriptive information (mean ± SD).

Mass (kilograms)	89.68 ± 10.66
Height (centimeters)	183.93 ± 8.58
Resistance training experience (number of days per week)	1.66 ± 1.61
Plyometric training experience (number of days per week)	0.58 ± 1.08
High school sports (total number of sports played)	1.41 ± 0.79
High school sport (years of participation)	5.33 ± 1.23
College intramural sport (years of participation)	3.00 ± 1.41
College varsity sport (years of participation)	0.41 ± 1.16

RESULTS: For the HD, no correlation was observed for GRF (r = -.22, p = .50) or RFD (r = -.14, p = .67). For the TD, no correlation was observed for GRF (r = -.29, p = .37) or RFD (r = -.28, p = .37). Average measure Interclass correlation coefficients for the heel and toe durometer were .95 (p = .69) and .92 (p = .53), respectively. Coefficients of variation for the heel durometer and toe durometer were 5.83% and 5.72%, respectively.

DISCUSSION: This is the first study to use a durometer to assess the density of the heel and toe regions of the shoe, and assess the relationship between sole density, GRF, and RFD, during the CMJ. Other studies have assessed the effects of shoe insoles on jump height, (Gregory et al., 2018; Selish et al., 2015; Stefanyshyn & Nigg, 2000; Stefanyshyn & Fusco, 2016; Stefanyshyn & Wannop, 2016) and the effect of shoe mid-sole durometer on lower extremity dynamics during running (MacLean, Davis & Hamill, 2009). However, no studies have assessed the density of the heel and toe regions and its relationship to the kinetics of the CMJ. Data from the current study shows that there is no relationship between HD and GRF or RFD, as well as TD and GRF or RFD.

Other research examining the role of shoe properties and modifications in improving performance has produced mixed results. Some research failed to find any advantage associated with different types of shoes or the addition of aftermarket insoles. For example, changes to shoe stiffness had no effect on jump height (Firminger et al., 2019). In this case, three different shoes in increasing longitudinal stiffness were tested resulting in no significant correlation between shoe stiffness and jump height, although a difference in Achilles tendon strain was found. Other research demonstrated that commercially available insoles, compared to the control shoe condition, did not improve either the CMJ or standing long jump performance (Selish et al., 2015).

In contrast to the aforementioned investigations and the current study, some evidence shows that shoe properties, or modifications of shoes, produce small improvements in performance. The role of mid-sole durometer along with the addition of orthotics has been studied. Results revealed that rearfoot eversion velocity was lower in shoes with harder mid-soles (MacLean, Davis & Hamill, 2009). Other research demonstrated that the addition of carbon fiber insoles influenced shoe stiffness, which positively affected jump height during the CMJ (Gregory et al., 2018; Stefanyshyn & Nigg, 2000). In one study, subjects performed three countermovement jumps wearing a control shoe with its' original 5 mm of ethyl vinyl acetate midsole, and one with the addition of carbon fiber plates. Subjects jumped an average of 1.7 cm higher while wearing the shoe with the added carbon fiber plates (Stefanyshyn & Nigg, 2000). Furthermore, carbon fiber insoles, including a stiff version for men and a moderate flexibility version for women, resulted in a 2.5% improvement in CMJ height, irrespective of gender (Gregory et al., 2018).

Therefore, shoe sole density as determined in the current study, variability in sole stiffness (Firminger et al., 2019), or the use of commercially available insoles (Selish et al., 2015) did not influence jumping kinetics or performance. On the other hand, mid-sole durometer or the addition of moderately stiff or stiff carbon fiber insoles improved jump performance (Gregory et al., 2018; MacLean, Davis & Hamill, 2009; Stefanyshyn & Nigg, 2000).

The current study demonstrated that the durometer is reliable for assessing shoe sole density. Previous research that used the durometer to assess the effect of shoe wear and endurance performance either did not assess reliability or did not report it (Cornwall & McPoil, 2017; MacLean, Davis & Hamill, 2009). Thus, the current study is the first to determine that the durometer is reliable for assessing shoe sole density.

Future research should further assess the role of shoe sole durometer on performance. This includes assessing shoe sole properties of other areas of the sole, and during other type of activities such as agility performance where a difference in the coefficient of friction may yield an advantage.

CONCLUSION: This study did not reveal any correlation between shoe sole durometer and the kinetics associated with the CMJ. Thus, jumping kinetics do not appear to be mediated by shoe sole density characteristics. Durometers such as the one used in this study are reliable for assessing shoe sole properties.

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