DOES INSOLE HARDNESS AFFECT THE DYNAMIC POSTURAL STABILITY OF BASKETBALL ATHLETES DURING JUMP LANDING?

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ABSTRACT. This study aimed to examine the effects of shoe insole hardness on the dynamic postural stability of basketball athletes during jump landing manoeuvres. Twenty college basketball athletes were recruited to complete a single-leg jump landing task on a force plate in three insole conditions (soft-, rigid- and no-insole). Kistler force plate and Pedar-X insole system were used to collect the ground reaction force (GRF) and plantar pressure data. Dynamic Postural Stability Index (DPSI), Anterior-Posterior Stability Index (APSI), Medial-Lateral Stability Index (MLSI), and Vertical Stability Index (VSI) were then calculated from GRF data. DPSI, APSI, MLSI, and VSI were statistically conducted among the three insole conditions by a one-way ANOVA with repeated measures. MLSI were decreased when wearing soft- and rigid insoles compared with no-insole condition ($p < 0.05$). However, there were no significant differences in APSI and VSI among the three insole conditions. In the midfoot region, contact areas were increased in the soft- and rigid insole than the no-insole condition ($p < 0.0001$). Dynamic balance of basketball athletes in the medial-lateral direction could be enhanced by wearing insoles during jump landings tasks. However, the postural stability of basketball athletes did not increase with insole hardness increasing.

KEY WORDS: dynamic postural stability; jump landing; insole hardness; ankle injury

DURITATEA BRANȚULUI AFECTEAZĂ STABILITATEA POSTURALĂ DINAMICĂ A JUCĂTORILOR DE BASCHET ÎN TIMPUL ATERIZĂRII LA SĂRITURI?

REZUMAT. Acest studiu are ca scop analiza efectelor durității branțului asupra stabilității posturale dinamice a jucătorilor de baschet în timpul aterizării la sărituri. S-au recrutat douăzeci de jucători de baschet universitar care să execute o aterizare cu un singur picior pe o platormă de forță în trei situații (cu branț moale, cu branț rigid și fără branț). S-au utilizat platforma de forță Kistler și sistemul de branț Pedar-X pentru a colecta datele privind forța de reacțiune a solului (GRF) și presiunea plantară. S-au calculae apoi indicele de stabilitate posturală dinamică (DPSI), indicele anterior-posterior (APSI), indicele medio-lateral (MLSI) și indicele de stabilitate verticală (VSI) din datele GRF. S-au calculat statistic indicii DPSI, APSI, MLSI și VSI în cele trei situații utilizând analiza ANOVA unidirecțională cu măsurători repetate. Indicele MLSI e scăzut la purtarea unor branțuri moi și rigide, comparativ cu situația fără branț ($p < 0,05$). Cu toate acestea, nu au existat diferențe semnificative în cazul indicilor APSI și VSI în cele trei situații. În regiunea mediană a piciorului, zonele de contact au fost mai mari în cazul purtării branțului moale și a celui rigid decât în situația fără branț ($p < 0,0001$). Echilibrul dinamic al jucătorilor de baschet în direcția medio-laterală ar putea fi îmbunătățit prin purtarea branțurilor în timpul aterizării la sărituri. Cu toate acestea, stabilitatea posturală a jucătorilor de baschet nu a crescut odată cu creșterea durității branțului.

CUVINTE CHEIE: stabilitate posturală dinamică; aterizare la săritură; duritatea branțului; leziunea gleznei

LA DURETÉ DE LA SEMELLE INTERNE AFFECTE-T-ELLE LA STABILITÉ POSTURALE DYNAMIQUE DES JOUEURS DE BASKET LORS DE LA RÉCEPTION DES SAUTS?

RÉSUMÉ. Cette étude a le but d'examiner les effets de la dureté de la semelle interne de la chaussure sur la stabilité posturale dynamique des joueurs de basket lors de la réception des sauts. Vingt joueurs de basketball universitaire ont été recrutés pour effectuer une réception de saut à une jambe sur une plateforme de force dans trois situations (semelle souple, semelle rigide et sans semelle). La plateforme de force Kistler et le système de semelle interne Pedar-X ont été utilisés pour collecter des données sur la force de réaction au sol (GRF) et la pression plantaire. L'indice de stabilité posturale dynamique (DPSI), l'indice de stabilité antérieure-postérieure (APSI), l'indice de stabilité médiale-latérale (MLSI) et l'indice de stabilité verticale (VSI) ont ensuite été calculés à partir des données GRF. Les indices DPSI, APSI, MLSI et VSI ont été statistiquement calculés dans les trois situations par une analyse ANOVA unidirectionnelle avec des mesures répétées. L'indice MLSI a diminué lors du port de semelles souples et rigides par rapport à l'absence de semelle ($p < 0,05$). Cependant, il n'y avait pas de différences significatives en ce qui concerne l'APSI et le VSI entre les trois situations. Dans la région du médio-pied, les zones de contact ont été augmentées dans le cas du port de la semelle souple et de la semelle rigide par rapport à la situation sans semelle ($p < 0,0001$). L'équilibre dynamique des joueurs de basket dans la direction médio-latérale pourrait être amélioré par l'utilisation des semelles pendant les réceptions des sauts. Cependant, la stabilité posturale des joueurs de basket n'a pas été augmentée avec l'augmentation de la dureté de la semelle interne.

MOTS CLÉS: stabilité posturale dynamique; réception de saut; dureté de la semelle interne; blessure à la cheville

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INTRODUCTION

Ankle injuries are among the most common and severe injuries sustained in basketball games [1], which induce pain, crepitus, and instability [2]. It leads to 53.7% of the total time lost for the basketball players [3]. The tremendous jump landing manoeuvres in basketball games are one of the leading causes of ankle injuries. The immediate reason is that the landing impacts of 3.5-9 times bodyweight acting on the lower extremities, especially on the ankle joint. The elastic ankle joint might not resist those high-impact loads [1, 4].

External ankle supports (e.g., ankle brace) or internal foot orthotics (e.g., shoe insole) were commonly used to improve postural control of basketball athletes with ankle injuries [5, 6]. Ankle brace would decrease the inversion/eversion angle of the ankle joint, while limiting the range of motion (ROM) of the ankle joints in the meantime [7], which may restrict the sports performance of basketball athletes. Therefore, basketball players are reluctant to wear orthoses to participate in basketball games. Recent studies showed that internal foot orthotics such as shoe insole could increase the lateral stability of older adults via stimulating plantar proprioception and enhancing signal input of the nervous system.

The insole hardness would affect the postural stability [8-12]. Ankle motion in the medial-lateral plane is negatively related to insole hardness (soft soles cause increased ankle movement). Xingda Qu *et al*. [13] studied the effects of different insoles on postural stability in older adults and reported that rigid insole was associated with better dynamic postural stability compared to soft insole. However, to the author's best knowledge, whether insole hardness could affect the dynamic postural stability of basketball players remains unknown.

Thus, the purpose of this study was to assess the dynamic postural stability of basketball athletes during jump landings manoeuvres while wearing insoles with varying hardness. It was hypothesized that: 1) the dynamic postural stability of the basketball athletes would be improved when wearing insoles compared to no-insole conditions; 2) dynamic postural stability of basketball athletes would be improved with the insole hardness increasing.

MATERIALS AND METHODS

Participants

Twenty healthy young college basketball athletes were recruited in this study (10 males and 10 females, age: 20.3 ± 1.2 years; height: 177 ± 8.1 cm; weight: 72.3 ± 7.8 kg; BMI: 21.2 ± 2.9 kg/m^2). None of the participants had undergone back or lower limb surgery, neurological or vascular disease, or lower extremity musculoskeletal diseases in the previous six months. None of the participants consumed drugs/alcohol or engaged in strenuous physical activity within 24 hours. Within 24 hours of tests, participants should abstain from strenuous physical activity. Each participant was informed of the risks of this study before enrollment. Each participant provided written informed consent, which the University's Institutional Review Board approved (No. 102772019RT054).

Materials

All participants were required to wear a pair of traditional basketball shoes (KT3 high-top, ANTA, Quanzhou, China) with three insole conditions: (1) soft insole, (2) rigid insole, and (3) no insole. The two insoles were identical in material (EVA foam), thickness, and shape except for hardness. The insole hardness was determined using the Shore C classification system, with scores ranging from Shore C 20 (soft) to Shore C 50 (rigid). The insole thickness is 6mm, which is commonly used in commercial basketball shoes. The material and shape of the insoles were chosen for their frequent use in recreational sports. Shoe Sizes 37–43 were available for this study.

Test Protocol

A force plate (9281EA, Kistler Corporation, Switzerland) and a Pedar-X insole system (Pedar-X® system, Novel Inc, Munich, Germany) were used to collect ground reaction force (GRF) data at a sampling rate of 200 Hz during anterior-posterior (AP) jumping tasks. Wikstrom's dynamic postural stability test followed the jump protocols based on previous studies [14]. Participants were instructed to randomly complete the trial in three conditions: soft insoles, rigid insoles, and no insoles. The participants stood behind the force plate with 40% of their body height during the test, with a 30-cm hurdle put halfway between the starting position and the force plate [14]. Then they were instructed to perform the following actions: jump in the anterior direction over the hurdle using a two-footed jump, land on the force plate with their non-dominant limb, and try to maintain stability as quickly as possible, place their hands on their hips once stabilized, and remain still for 10 seconds while looking forward. The dominant leg is determined to be the preferred leg to kick the ball [15]. The trial would be discarded if the participant failed to jump or the dominant limb touched the ground. Three successful trials in each insole condition were collected, followed by two minutes of rest.

Data Reduction

Data reduction was performed using a custom MATLAB (v2016a, Natick, MA) script file for dynamic postural stability. The force plate data were filtered using a fourth-order bidirectional low pass Butterworth filter with a cutoff frequency of 50 Hz. For data reduction, three trials for each insole condition were averaged. As illustrated in Equations 1-4, the primary variable for the AP jump landing manoeuvers was the dynamic postural stability index (DPSI). DPSI was calculated from the first three seconds of ground reaction force (GRF) data following initial contact, defined as the instant the vertical GRF exceeded 10 N [14]. DPSI is a composite of anterior-posterior (APSI), medial-lateral (MLSI), and vertical (VSI) GRF that is highly reliable [14]. A lower stability index indicated that the system was balanced [16]. The following equations were used to derive these variables:

$$\mathrm{APSI} = \sqrt{\frac{\sum(0-GRF_y)^2}{number\ of\ data\ points}} \div Body\ Weight \quad (1)$$

$$\mathrm{MLSI} = \sqrt{\frac{\sum(0-GRF_x)^2}{number\ of\ data\ points}} \div Body\ Weight \quad (2)$$

$$\mathrm{VSI} = \sqrt{\frac{\sum(Body\ Weight-GRF_z)^2}{number\ of\ data\ points}} \div Body\ Weight \quad (3)$$

$$\mathrm{DPSI} = \sqrt{\frac{\sum(0-GRF_x)^2+\sum(0-GRF_y)^2+\sum(Body\ Weight-GRF_z)^2}{number\ of\ data\ points}} \div Body\ Weight \quad (4)$$

The mean plantar contact area (CA, mm^2) in three anatomical regions (masks) was calculated in this study (Novel Electronics Inc). These regions included rearfoot (RF, 0%–27%), midfoot (MF, 27%–55%), and forefoot (FF, 55%–100%) [17, 18] (Fig. 1 illustrates regions division in detail).

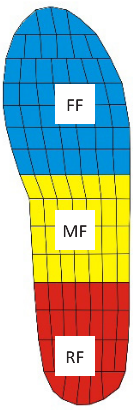

Figure 1. Three anatomical foot regions were defined in this study: FF (forefoot), MF (midfoot), RF (rearfoot)

Statistical Analysis

For APSI, MLSI, VSI, DPSI, and CA, one-way analyses of variance (ANOVA) with repeated measures were conducted. When a significant main effect was observed, LSD post hoc tests were conducted. η^2 were calculated for each ANOVA. The level of significance was set at 0.05. Intraclass correlation coefficient (ICC) and standard error of the mean (SEM) analyses were used to determine the reliability of the APSI, MLSI, VSI, and DPSI in the first 3-seconds sampling interval. All statistical analyses were conducted by SPSS (Version 22.0, SPSS, Inc., Chicago, IL, U.S.A.).

RESULTS

Reliability statistics are presented in Table 1. ICCs were moderate-excellent (0.636–0.783). The three insole conditions in the APSI, MLSI, VSI, and DPSI, indicate a good agreement.

Table 1: ICC and SEM of the three insole conditions in MLSI, APSI, VSI, and DPSI

Variables	ICC			SEM		
	no	soft	rigid	no	soft	rigid
MLSI	0.636	0.650	0.695	0.008	0.007	0.007
APSI	0.734	0.631	0.664	0.013	0.010	0.014
VSI	0.757	0.640	0.742	0.039	0.033	0.040
DPSI	0.783	0.658	0.742	0.040	0.034	0.040

Note: ICC represents Intraclass Correlation Coefficient; SEM represents Standard Error of the Mean. MLSI: Medial-lateral Stability Index; APSI: Anterior-posterior Stability Index; VSI: Vertical Stability Index; DPSI: Dynamic Postural Stability Index.

Results from the ANOVA indicated a significant insole effect in MLSI ($F_{2,38}$=5.106, p = 0.011, η^2 = 0.221). LSD post-hoc pairwise tests revealed that MLSI was significantly smaller in the soft insole and rigid insole condition compared to no insole condition ($p < 0.05$). However, there were no significant differences in APSI, VSI, and DPSI among the three insole conditions (Fig.2).

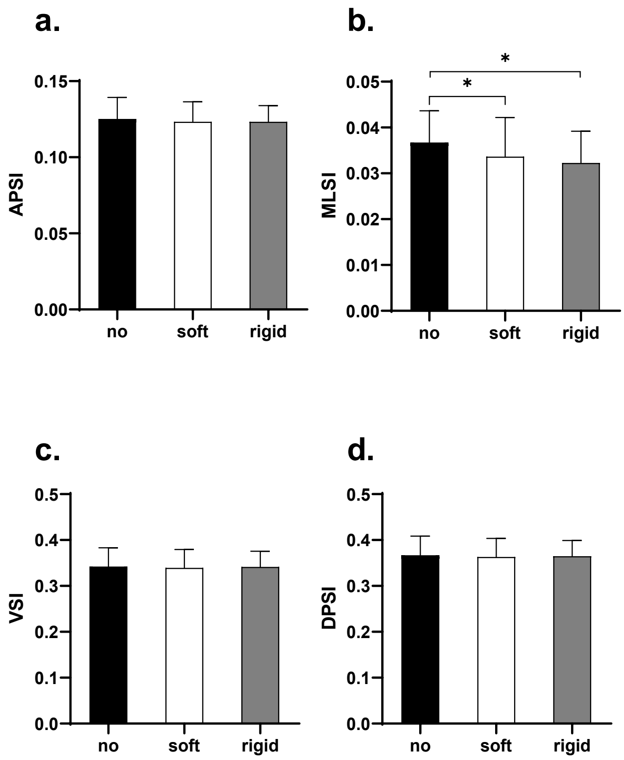

Figure 2. Dynamic stability variables in the no-, soft-, and rigid insole conditions, a) anterior-posterior stability index (APSI); b) medial-lateral stability index (MLSI); c) vertical stability index (VSI) and d) dynamic postural stability index (DPSI); Error bars are standard deviation; * indicates a significant difference between the two conditions; n = 20 in each case

As shown in Figure 3, a significant insole effect was observed in CA ($F_{2,38}$=10.988, p <0.0001, η^2 = 0.366) in the MF region. Post-hoc comparisons showed that the CA was significantly lower in the no insole condition compared to the soft- and rigid insole conditions in the MF region ($p < 0.05$). However, no significant differences in CA were observed in the forefoot and rearfoot regions among the three insole conditions ($F_{2,38}$=1.167, p = 0.322, η^2 = 0.058; $F_{2,38}$=1.187, p = 0.316, η^2 = 0.059).

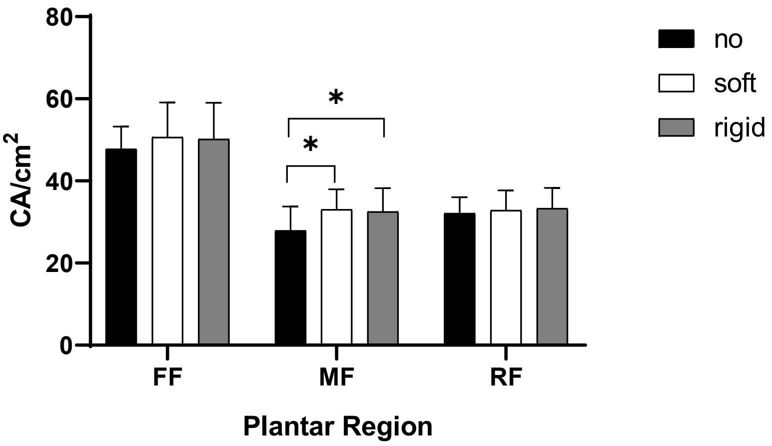

Figure 3. Contact area in the no-, soft-, and rigid insole conditions, CA: contact area; FF: forefoot; MF: midfoot; RF: rearfoot; Error bars are standard deviation; * indicates a significant difference between the two conditions; n = 20 in each case.

DISCUSSION

The purpose of this study was to determine whether insole hardness affects dynamic stability during single-leg jump landings. Results partially supported our first hypothesis that a soft or rigid insole would enhance dynamic postural stability of basketball athletes in medial-lateral directions compared to no insole condition. However, the second hypothesis that dynamic postural stability of basketball athletes was improved with insole hardness increasing was not supported.

Results of our study support the first hypothesis. Results showed that MLSI was significantly lower in the soft insole and rigid insole conditions for jump landing basketball players than the no insole condition. These results can be attributed to several reasons. First, some research found that stability improves due to increased midfoot contact area while wearing a full arch support insole [19], which is consistent with our study (midfoot contact was significantly lower without insole than insole conditions). Second, the support of the insole also enhanced stability. Some studies suggested that the arch support of the insole supported the medial midfoot, limited foot motions in medial-lateral directions [19, 20]. Finally, the contact areas between foot sole and shoe insole were linked to the facilitation of a neutral ankle position. Adjusting the ankle position by the insole was thought to balance the muscles and structures around the ankle joints, facilitated changes in the coronal and sagittal planes of the feet, impacted the surrounding tissues, created aberrant foot motion [21].

Secondly, an insole may assist in maintaining stability of basketball athlete by providing improved sensory feedback from the foot [16, 22]. It has been established that activating the plantar proprioceptive mechanoreceptors is critical for athletes to maintain balance and dynamic stability during sports-related movements. Previous studies have shown that textured insoles can improve the balance control ability of the human body by increasing the stimulation to the foot sole [9, 23]. These results indicated that more sensory input might be caused by the increased contact area between the foot sole and shoe insole when wearing shoes with insoles. It indicated that the insole would improve the dynamic postural stability of basketball athletes in the medial-lateral direction compared to the no insole condition.

The results of our study rejected the second hypothesis. No significant differences were observed in all three insole conditions in MLSI, APSI, VSI, and DPSI. However, Xingda Qu's study [13] showed that rigid insoles were better than soft insoles in DPSI for older adults, suggesting that rigid insoles could improve DPSI. It was inconsistent with our study, which may be due to differences in the age of the participants and experimental tasks. Older subjects were in a declining stage of proprioception and may have been more responsive to insole stimulation [24, 25]. Compared with older adults, young adults have better balance adjustment ability. The change of insole hardness was not enough to change the dynamic stability of young adults in the landing and other challenging tasks [26].

It is critical to consider some of the limitations in this study when interpreting our findings. One limitation of this study was that only the effect of insole hardness on dynamic stability was investigated; future research should focus on the effects of insole materials, shape, and thickness on postural control of athletes when they perform high-risk tasks. In addition, we did not conduct any direct sensory or motor function measurements. As a result, this study cannot provide direct insight into the mechanisms underlying the benefits of insole intervention in postural stability.

CONCLUSIONS

Results of our study indicated that the dynamic stability of basketball athletes was increased by the shoe insoles in the medial-lateral direction during jump landing manoeuvres. However, a rigid insole did not contribute to the increased dynamic stability of basketball athletes during jump landing manoeuvres. Further studies should consider the insole material, arch support height, and insole thickness for better dynamic postural control in landing-related sports.

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