DO SHOE COLLAR HEIGHT INFLUENCE THE KINEMATICS AND KINETICS OF ANKLE JOINT IN SAGITTAL PLANE MOVEMENT

Yang Yang, Xi Wang and Weijie Fu

Key Laboratory of Exercise and Health Sciences of Ministry of Education, Shanghai University of Sport, Shanghai, China

This study aims to investigate the effects of wearing high (HS) & low-top (LS) basketball shoes on the ankle joint kinematics, kinetics, and performance in the sagittal plane during different maneuvers. 12 subjects performed weight-bearing dorsiflexion (WB-DF) movement, drop jumps (DJ), and lay-up jumps (LU) in two shoe conditions. Wearing HS can significantly reduce ankle joint excursion in WB-DF. No significant differences were found in jumping height and kinematics between the two shoes. In LU, peak plantarflexion torque and power were significantly lower in HS. The high-top shoes adopted in this study did not restrict the ankle dorsiflexion performance during actual jumping. Thus, high shoe collar height would be applied to practical with caution of affecting the partial kinetic characteristics of the ankle joint in the sagittal plane.

KEY WORDS: shoe collar height; ankle joint; kinematics; kinetics; jumping maneuver

INTRODUCTION: Jumping maneuvers, including double-leg drop jump (DJ) and single-leg lay-up jump (LU), are basic forms in basketball training and competitions (McClay et al., 1994). These jumping/landing maneuvers combined with high-intensity confrontation are major risk factors of ankle injury among basketball players with the reported incidence rates of 3.85 per 1000 participations (Leanderson et al. 1993; McKay et al. 2001).To reduce the risk of ankle sprains, high-top basketball shoes has been applied and showed potential in preventing ankle sprains in basketball (Robinson et al., 1986).
Current investigations on high-top shoes have been mainly focusing on ankle frontal plane motion (Fu et al., 2014). However, it is still noteworthy that both the single-leg or double-leg jumps are the motion in the sagittal plane and whether the collar height could affect the flexion and extension of the ankle joint or the performance in actual conditions is largely unknown. Additionally, there is also an allegation that high-top shoes may limit ankle dorsiflexion range of motion in certain scenarios (vertical jump and leap), and subsequently negatively affect athletic performance (Brizuela et al., 1997). Meanwhile, some studies have reported that high-top shoes and ankle braces restricted ankle dorsiflexion kinematics during landing and cutting maneuvers (Lam et al., 2015).
Therefore, this study aims to investigate the effects of wearing high-top and low-top basketball shoes on: 1) ankle angle excursion during weight-bearing dorsiflexion movement; 2) ankle joint kinematics (contact angle and range of motion), kinetics (torque, power, and stiffness), and sports performance (jump height) in the sagittal plane during drop jumps (DJ) and layup jumps (LU).

METHODS: Twelve male collegiate basketball players (age: 23.7±0.6 yrs, height: 180.0±4.6 cm, body mass: 73.6±6.9 kg) with a minimum of 4 years of experience in basketball event were recruited for this study. The protocol was approved by the university institutional review board and all participants provided written informed consent before the completion of any study procedures. High-top (HS) and low-top basketball shoes (LS) used in this study were obtained from the same footwear manufacturer. Both shoes had an identical design (outsole, midsole, and appearance) except for a 7 cm difference in shoe collar height, which was measured from the lowest point of LS collar to the highest point of HS collar. Weight-bearing dorsiflexion (WB-DF) test: Each participant was required to stand in natural stance position with feet apart in parallel. After receiving the instruction “Start” from the experimenter, the participant squatted with ankle dorsiflexed gradually until he could no longer subjectively squat or a heel off (lifting from the floor) could be observed (Figure 1). For DJ, participants were instructed to "Step off the front of the platform, land with both feet on the 2 force plates separately, and then jump as high as possible with the shortest possible contact time" For the layup (LU), a common point-scoring maneuver in basketball, all participants stepped on the force platform with the second contralateral step after the first forward step, and then took-off to release the ball into the goal. 3D kinematics (Vicon, 120 Hz) and ground reaction force (Kistler, 1200 Hz) were measured simultaneously. The variables of interest included: the ankle angle at touchdown (θ_0), the maximum and minimum ankle angles (θ_{min}, θ_{max}), the ankle range of motion ($\theta_{ROM} = \theta_{max} - \theta_{min}$), the ankle angle excursion during the downward phase ($\Delta\theta = \theta_0 - \theta_{min}$), the peak torque ($M_{max}$), peak power ($P_{max}$), and joint stiffness ($k$) of ankle joint. Jump height, calculated using $v_0^2 / 2g$ (where v_0 is the vertical take-off velocity), was used to reflect jumping performance (Bosco et al., 1983). Paired t-tests were used to determine the differences between high-top shoe and low-top shoe conditions (17.0, SPSS Inc., U.S.A.). The significance level was set at α=0.05.

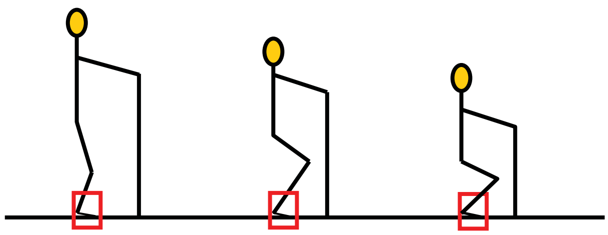

Figure 1 Diagram depicting the measurement of weight-bearing ankle dorsiflexion

RESULTS:

Sagittal plane ankle kinematics

In the WB-DF, the θ_{min} was significantly greater in HS compared to LS (p < 0.05) while the θ_{ROM} was also significantly lower in HS (p < 0.05). However, during DJ and LU, no significant differences in the ankle angle at touchdown (θ_0), the minimum (θ_{min}) and maximum (θ_{max}) ankle angle, the ankle range of motion (θ_{ROM}), and ankle angle excursion ($\Delta\theta$) were observed between the two shoes. In addition, no significant differences were observed in the jump height between the two shoes.

Table 1 Effect of shoe collar height on ankle joint kinematics in the saggital plane in weight-bearing dorsiflexion (WB-DF), drop jump (DJ), and lay-up jump (LU) tasks

Tasks	Shoes	θ_0/(°)	θ_{min}/(°)	θ_{max}/(°)	θ_{ROM}/(°)	$\Delta\theta$/(°)	h /cm
WB-DF	HS	N/A	85.0±8.9	112.8±3.5	27.0±6.7	N/A	N/A
	LS	N/A	77.1±7.3*	108.9±4.8	32.2±6.6*	N/A	N/A
DJ	HS	125.6±9.2	90.8±11.2	140.7±8.7	50.0±9.3	34.7±7.9	0.34±0.05
	LS	125.8±6.1	88.1±7.5	140.3±8.1	52.1±8.0	37.7±7.9	0.34±0.05
LU	HS	117.8±5.4	104.3± 7.2	136.2±10.3	31.8±8.1	13.6±5.8	0.38±0.05
	LS	116.0±6.0	103.6±5.7	134.1±10.6	30.6±6.7	12.4±4.5	0.41±0.04

Note: HS: high-top shoe; LS: low-top shoe; θ_0: the ankle angle at touchdown; θ_{min}, θ_{max}: the maximum and minimum ankle angles; θ_{ROM}: the ankle range of motion, ($\theta_{ROM} = \theta_{max} - \theta_{min}$); $\Delta\theta$: the ankle angle excursion during the downward phase; h: the jump height. * Significantly different from HS with p < 0.05.

Sagittal plane ankle kinetics

In LU, the peak torque (M_{max}) and the peak power (P_{max}) were significantly greater in LS compared to HS (Figure 2). However, no differences were observed between the shoe conditions in the *k*. In addition, in DJ task, no significantly differences were observed in M_{max}, P_{max} and joint stiffness (*k*).

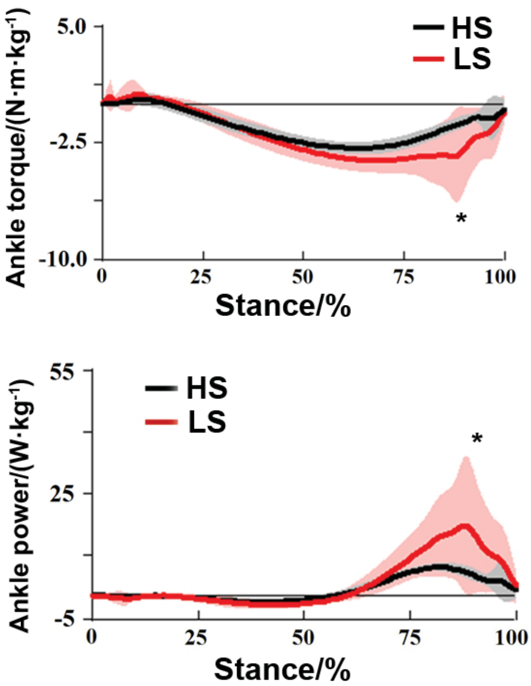

Figure 2. Comparison of the high-top (HS) and low-top (LS) shoes on the ankle torque (upper) and the ankle power (lower) during the stance phase of the lay-up jump.

DISCUSSION: We found that shoe collar height affected ankle angle in weight-bearing dorsiflexion movement and the torque & power output during single-leg jumping, though it did not lead to changes in jumping height of the two jumping maneuvers.

In the WB-DF test, wearing high-top shoes significantly reduced the dorsiflexion of the ankle joint in the sagittal plane, which is consistent with previous study. High-top design and the flexibility of the material against the deformation of shoes have been proved to significantly reduce peak ankle dorsiflexion, and consequently relieve the tension on the heel tendon in quasistatic condition (Rowson et al., 2010). However, results in the current study showed that high-top shoes did not restrict ankle flexion/extension during actual jumping. As one would expect, ankle joint ROM is greater in a jumping maneuver than a quasi-static ankle dorsiflexion movement. In particular, the ankle joint ROM in DJ was beyond 50° which mainly due to large excursion of plantarflexion. The minimum angle of the ankle joint was nearly 90°, that is, minimal dorsiflexion angle occurs. Therefore, shoe collar height cannot restrict ankle dorsiflexion during push-off phase.

Several research have investigated the impact of high-top shoes on sagittal plane ankle biomechanics. Greene et al. (2015) observed that wearing high-top shoes did not significantly affect the ankle flexion/extension, instead, wearing an ankle brace significantly reduced the joint mobility in the touchdown phase. Venesky et al. (2006) also reported that wearing an ankle brace can effectively stabilize the ankle joint but it may restrict the sagittal plane movement. These findings suggested that ankle brace was more capable in limiting ankle sagittal plane movement than high-top shoes. This effect can be reflected by the dorsiflexion test results in the present study that wearing high-top shoes can reduce the ankle joint mobility in the sagittal plane. Nevertheless, its restriction was insufficient to provide a significant influence during touchdown and push-off phases. The above studies showed that considering only the increased stability of the ankle joint when designing high-

top shoes may affect the flexion/extension performance of the ankle joint in the sagittal plane. The further quantitative study is needed to determine the boundary.
On the other hand, Boyer et al. (2009) showed that wearing different lateral stable sport shoes can affect the plantartorque and power of the ankle joint in push-off. The influence depends on the net contribution that is activated by the muscle around the ankle joint on a large level. In particular, when the limbs exert maximum force, such as in fast movements, the coordination of active and antagonist muscles is likely to occur (Marsden, Obeso, & Rothwell, 1983). In most running and jumping maneuvers, the performance depends on the total power output of hip, knee, and ankle joints (Stefanyshyn & Nigg, 2000). Therefore, an increase in single ankle plantarflexion power does not necessarily lead to an improvement in jumping height.

CONCLUSION: In weight-bearing dorsiflexion test, wearing high-top shoes can effectively reduce ankle joint excursion in the sagittal plane. However, in DJ or LU, shoe collar height did not affect ankle kinematic characteristics in the sagittal plane. Therefore, the high-top shoes adopted in this study did not restrict the flexion/extension performance of the ankle joint during actual jumping. Different shoe collar heights did not alter jump performance, but can influence the peak plantarflexion torque and power of during push-off of LU. Thus, high shoe collar height would be applied to practical with caution of affecting the partial kinetic and kinematic characteristics.

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