The Effects of Different Shoe Bending Stiffness on Kinematics of Metatarsophalangeal, Ankle, Knee, and Hip Joints in Jumps

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SUMMARY
The aim of this research was to find out the effects of different shoe midsole bending stiffness on the kinematics of metatarsophalangeal, ankle, knee, and hip joints. Thirty male basketball players were requested to wear different midsole stiffness of shoes to achieve two types of jumps. Two separated groups' kinematics data were collected. We found that the stiffer shoe could restrain metatarsophalangeal joint movement and influence the range of motion of ankle joint. But there was no significant effect on the kinematics of knee and hip joints. These findings might be a suggestion for athletes and manufacturers who wanted use sport shoes to improve sport performance.

INTRODUCTION
All athletes and coaches want to improve sports performance. Hence the study that focuses on metatarsophalangeal joint (MPJ) which used to be out of the spotlight but now has proposed a new way. Krell and Stefanyshyn's study has showed that male and female 100 meters Olympic runner's maximum extension velocity of MPJ and the angle of metatarsophalangeal joint touchdown were correlated with their sport performance [1]. Another study also found that joint kinetics of the low limbs and sport performance would be affected by the changes of flexion and extension of metatarsophalangeal joint [2]. Stefanyshyn et al. also proposed that reducing metatarsophalangeal joint motion by increasing its stiffness could increase positive work because of the negative work done by MPJ [3].

To sum up, the purpose of this study was to find out whether the metatarsophalangeal joint kinematics could be changed if using different shoe midsole bending stiffness. This research will be the cornerstone of a new way of improving sport performance.

METHODS
Thirty male basketball players (age: 21.2±1.3 years, heights: 183.5±5.0 cm) were recruited in this study. All the subjects should wear the same experimental suits. Before the test all volunteers should warm up and run on the treadmill with the speed of 8 km/h for 8 minutes. The shoes which were used in the study were divided into two groups. One was the testing shoe group which had a stiffer midsole (TS). The other was a control shoe group which had a normal midsole with identical outsole and appearance (CS).

This study uses all random double-blind principle. Before the test all the subjects were given a random order to make sure which shoes they wear first and the assistant who gives subject a shoe also do not know which group each pair of shoes belongs to. Our test includes two types jump: counter-movement jump(CMJ) and single leg jump(SLJ). The former is a classic test, while the latter is used to simulate the layup action in basketball. Vicon system was used to collect kinematics data (240 Hz) and Kistler force plate was used to collect kinetics data (1200 Hz) simultaneously. Kinematics data were then used to calculate the maximum metatarsophalangeal joint extension and flexion angle, range of motion in metatarsophalangeal joints, maximum metatarsophalangeal joints extension and flexion velocity as well as the same variable of ankle, knee, and hip joints of the dominate lower-limb. A 2 × 2 (shoe × jump style) two-way repeated measures analysis of variance was applied to compare the changes in the above variables. The significant level was set at $\alpha = 0.05$.

RESULTS AND DISCUSSION
During the count-movement jump, the patterns of the metatarsophalangeal joint velocity-time curves was similar between TS and CS which was shown in the figure one. But we found that the maximum metatarsophalangeal joints extension velocity in TS was significantly smaller than in CS during countermovement jump test ($p<0.05$) (Table 1). It might be resulted by the test group shoes have more stiffness middle sole and the shoe sole deformation becomes more difficult. Moreover, we could also find that the test group's wave on Figure one was obviously gentler than control group's. The reason of this phenomenon is that the sport shoes with more stiffness sole might be restricted metatarsophalangeal joint's range of motion. During single leg jump test, ankle joint's range of motion has significant difference (Table 1).

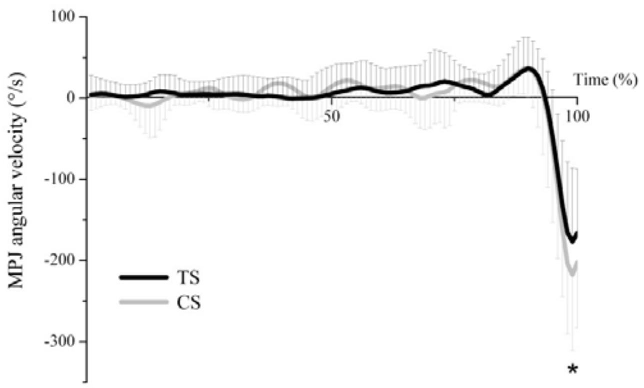

Figure 1 Metatarsophalangeal joint velocity changes on counter-movement jump by standardizing

After comparing two different types of jump, we could find out that ankle joint's maximum plantar-flexion and dorsiflexion angle, range of motion, maximum dorsiflexion velocity and knee joint' maximum extension ankle, range of motion, maximum extension velocity and hip joint's maximum flexion angle, range of motion, maximum extension velocity all had significant difference(Table 2).

CONCLUSIONS
Increasing the shoes' middle sole stiffness would significantly reduce the maximum extension velocity of metatarsophalangeal joint in countermovement jump, as well as the velocity change of metatarsophalangeal joint throughout the jumps. The stiffer shoe would also

indirectly affect other joints, such as increasing the range of motion in ankle during a single leg jump.

Using different types of jumps has a strong effect on ankle, knee, and hip joints kinematics. So we should pay attention to the appropriate target movement based on the research demanding.

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Table 1: The effect of different midsole stiffness of shoes on kinematics data of metatarsophalangeal joint.

Jump type	Shoes type	Maximum Extension Angle (°)	Maximum Flexion Angle(°)	ROM (°)	Maximum Extension Velocity (°/s)	Maximum Flexion Velocity (°/s)
CMJ	CS	37.1±7.9	-25.5±6.5	11.6±3.1	73.7±23.5	252.6±70.6
	TS	34.4±4.9	-25.1±4.6	9.3±2.7	77.4±21.2	198.1±63.8 *
SLJ	CS	29.7±5.2	-22.2±4.9	7.5±2.4	87.1±25.7	69.1±25.6
	TS	31.2±9.8#	-23.3±8.6	7.9±2.2#	78.3±22.4	56.4±31.2#

Table 2: The effect of different midsole stiffness of shoes on kinematics data of ankle, knee, and hip joints.

Joint	Jump type		Maximum Flexion / dorsi-flexion Angle (°)	Maximum Extension /plantar-flexion Angle (°)	ROM (°)	Maximum Extension /plantar-flexion Velocity (°/s)
Ankle	CMJ	CS	35.5±8.8	-18.3±9.0	53.9±5.8	603.8±97.0
		TS	37.5±6.3	-17.8±9.6	55.3±7.7	632.8±95.2
	SLJ	CS	9.1±9.0	-18.3±10.4	27.4±10.1	245.0±94.3
		TS	9.6±6.9#	-20.3±9.4#	29.9±8.7*#	245.0±108.2#
Knee	CMJ	CS	-97.2±10.3	-9.2±5.7	88.0±9.3	835.9±82.0
		TS	-97.0±9.5	-8.4±6.4	88.6±9.9	831.5±77.3
	SLJ	CS	-53.6±5.7	-11.0±5.1	42.65±5.4	68.0±65.4
		TS	-55.0±6.7#	-10.5±5.6	44.5±6.2#	65.6±50.9#
Hip	CMJ	CS	101.3±14.9	16.7±7.0	84.5±12.9	303.4±65.8
		TS	100.0±13.5	15.3±6.8	84.6±10.5	298.9±60.9
	SLJ	CS	71.7±10.0	14.2±8.1	57.5±8.6	87.4±55.9
		TS	71.3±10.2	11.9±7.2#	59.4±8.6#	87.9±69.8#

Note: CS, control shoe. TS, stiffer testing shoe. * Indicate significant differences between the shoes in same jump type with $p<0.05$. # Indicate significant differences between the shoes in same shoe group with $p<0.05$.