EFFECT OF ARCH SUPPORT FOOT ORTHOSIS ON LOWER EXTREMITY LOADING AND KINEMATICS DURING THE REBOUND

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The purpose of this study was to determine whether arch support foot orthosis was capable of altering lower extremity loading and kinematics during the rebound. Nineteen female Division I basketball players participated in this study. Utilizing a repeated measures design, participants completed two rebound tasks with and without the arch support foot orthosis. Results showed that the selected arch support foot orthosis significantly decreased the peak impact force, knee internal rotation and foot inversion angle at the initial contact of the ground compared to those of the flat insole. It suggested that the use of the arch support foot orthosis can decrease the lower extremity loading and further decrease the risk of ACL injury in female basketball players.

KEY WORDS: basketball, anterior cruciate ligament injuries, peak impact force

INTRODUCTION: Per basketball game has shown that players perform an average of 70 jumps. Basketball players are often injured when landing from a jump. The knee joint accounts for 72% of these injuries. Previous study indicated that the majority of non-contact anterior cruciate ligament (ACL) injury occurred during jump landing (Kirkendall & Garrett, 2000).

A previous study indicated that the kinematic link is the coupling of frontal plane motion of the foot (inversion/eversion) with transverse and frontal plane motion of the lower leg through the subtalar joint (Joseph et al., 2008). Specifically, excessive subtalar pronation has been linked to increased knee internal rotation angle, hip adduction angle and hip internal rotation angle, and this can result in increased risk of ACL injury (Joseph et al., 2008).

In addition, the abnormal foot arch structure might lead to an inability to attenuate high impact forces which could impose extreme loads on the musculoskeletal system and result in the development of ACL injury. Therefore, it may be hypothesized that limiting the amount of pronation/eversion at the subtalar using foot orthosis could decrease knee internal rotation angle, hip adduction angle, hip internal rotation angle and impact force. The purpose of this study was to determine whether arch support foot orthosis was capable of altering lower extremity loading, transverses and frontal plane kinematics during the rebound.

METHODS: Nineteen female collegiate Division I basketball players (age: 20.0± 3.6 years; weight: 69.5 ± 6.6 kg, height: 174.7 ±5.6 cm) volunteered for this study. Exclusion criteria were a current lower extremity injury, any surgery in the lower extremities, or expressing an inability to perform the research protocol. Each participant gave informed consent before participation in this study.

Before the start of the trials, participants performed five minutes warm-up involving running at a self-selected pace and dynamic stretching. Participants were instructed to perform three trails of rebound in standardized footwears (Model s.y.m.B9025, LurngFurng, Inc., Taipei, Taiwan) with either a pair of arch support foot orthosis (Footdisc, Inc., Taipei, Taiwan) or a pair of flat insole (Model s.y.m.B9025, LurngFurng, Inc., Taipei, Taiwan). The tested conditions were randomized by casting lots. The rebound can be characterized by left leg

forward stepping followed by two-legged vertical jumping as high as possible as quickly as possible with arm swinging to simulate a basketball rebound movement during basketball competition (Figure 1). Participants were instructed to land from their jump on both feet on two separate force platforms.

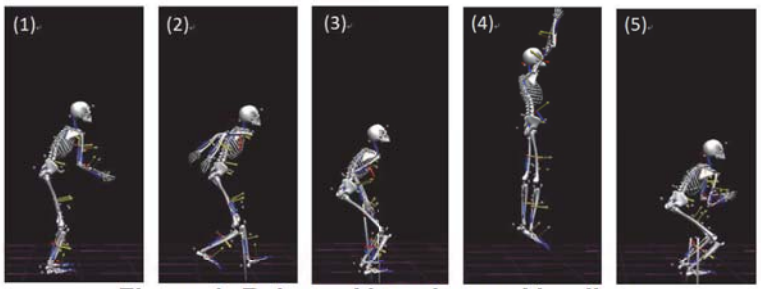

Figure 1: Rebound jumping and landing.

Kinematic data were collected with a motion analysis system (Motion Analysis Corporation, Santa Rosa, CA, USA) at 200-Hz sampling rate. Kinetic data were collected with two AMTI force platforms (AMTI Inc., Watertown, MA, USA) at 2000-Hz sampling rate. One platform collected the right leg data, whereas another collected left leg data. The cameras were synchronized to two force platforms. Kinematic and kinetic data were transformed and analyzed using the MotionMonitor software (Innovative Sports Training Inc., Chicago, Illinois, USA).

Peak impact force was calculated during landing after subject jumped in the air. Time to peak impact force was calculated from the foot initial contact to the instant of peak impact force. Joints angles on the transverse and frontal plane was calculated at the instant of foot initial contact. Jump height was calculated by subtracting the sacrum height in the upright standing posture from the maximal height after takeoff. The initial contact and takeoff was determined by assessing 50-Newton vertical ground reaction force threshold. Kinematic and kinetic data of the right leg which was the dominant leg for all participants were analyzed.

All statistical analyses were performed using SPSS 12.0 for Windows (SPSS, Inc., Chicago, IL, USA). All variables were compared between the arch support foot orthosis and flat insole by paired samples t-test. The level of significance was set at $p < .05$.

RESULTS: The peak impact force was significantly higher in the flat insole than in the arch support foot orthosis (p=.024). The knee internal rotation angle at initial contact was significantly higher in the flat insole than in the arch support foot orthosis (p=.049). The foot inversion angle was significantly higher in the flat insole than in the arch support foot orthosis (p<.008). The rest of variables showed no significance. Please, refer to Table 1.

Table 1
Kinetic and kinematic data

	flat insole	arch support foot orthosis	percentage differences
Peak impact force (BW)*	3.29 ± 0.57	3.14± 0.58	↓4.5%
Time to peak impact force (millisecond)	81.03± 12.17	82.12 ±12.47	↑1.3%
Knee internal rotation angle(degree)*	2.65± 7.33	0.03± 8.77	↓98.8%
Hip externalrotation angle (degree)	9.17± 5.39	8.27± 6.35	↓9.8%
Hip abduction angle (degree)	10.89± 4.81	9.11± 4.51	↓16.3%
Foot inversion angle (degree)*	9.7± 5.5	8.2± 5.0	↓15.4%
Jump height (meter)	0.39± 0.06	0.38± 0.06	↓2.5%

*Significant difference (p<.05).

DISCUSSION: The primary finding of this study was that there were significant decreases in peak impact force and knee internal rotation angle during rebound in female basketball players with the arch support foot orthosis. However, this study found that there were trends observed for decreases in hip external rotation and hip abduction angle and increases time to peak force with the arch support foot orthosis.

The foot arch structure connecting the human body and the ground plays an important role allowing it to act as a shock attenuator during landing (Fukano & Fukubayashi, 2009). The dysfunction of foot arch structure may increase the impact force. In addition, previous study indicated that landing with a high impact force may pose a high risk to the ACL injury (Bates, Ford, Myer & Hewett, 2013). Thus, in this study, the arch support foot orthosis could make the foot arch structure more functional to decrease the impact force during the rebound. In addition, may this be due to soft poron® metatarsal design under orthosis. This may be happen to attenuate impact force and prolong time to peak force.

The arch support foot orthosis have the capability of limiting pronation/eversion at the subtalar, which will be associated to the significantly decrease of knee internal rotation angle and trends of decreased hip external rotation and hip abduction angle (Tillman et al., 2003; Jenkins et al., 2009; Joseph et al., 2008). Previous study also indicated that increased knee internal rotation, hip external rotation and hip abduction angle may increase the risk of ACL injury (Withrow et al., 2006). In this current study, wearing the arch support foot orthosis significantly decreased the knee internal rotation angle and trends of decreased hip external rotation and hip abduction angle which meant it could further decrease the risk of ACL injury in female basketball players.

This study found high variabilities for some results. It was suggested that there were high variabilities among subjects on the rebound movement.

CONCLUSION: In summary, the arch support foot orthosis used in this study significant decreased the peak impact force and knee internal rotation angle and trends of decreases in hip external rotation and hip abduction angle and increases in time to peak force during the rebound in female basketball players. The arch support foot orthosis may be helpful to prevent ACL injury. Wearing arch support foot orthosis was recommended for female basketball players.

REFERENCES:

Bates, N.A., Ford, K.R., Myer, G.D. & Hewett, T.E. (2013). Timing differences in the generation of ground reaction forces between the initial and secondary landing phases of the drop vertical jump. *Clinical Biomechanics*, 28, 796-799.

Fukano, M. & Fukubayashi, T. (2009). Motion characteristics of the medial and lateral longitudinal arch during landing.*European journal of applied physiology*, 105, 387.

Jenkins, W.L., Williams, D.S., Durland, A., Adams, B. & O'Brien, K. (2009). Foot orthotic devices decrease transverse plane motion during landing from a forward vertical jump in healthy females. *Journal of Applied Biomechanics*, 25, 387.

Joseph, M., Tiberio, D., Baird, J.L.,Trojian, T.H., Anderson, J.M., Kraemer, W.J. & Maresh, C.M. (2008). Knee Valgus During Drop Jumps in National Collegiate Athletic Association Division I Female Athletes The Effect of a Medial Post. *The American Journal of Sports Medicine*, 36, 285-289.

Kirkendall, D.T. & Garrett, W.E. (2000). The anterior cruciate ligament enigma: injury mechanisms and prevention. *Clinical Orthopaedics and Related Research*, 372, 64-68.

Tillman, M.D., Chiumento, A.B., Trimble, M.H., Bauer, J.A., Cauraugh, J.H., Kaminski, T.W. & Hass, C.J. (2003). Tibiofemoral rotation in landing: the influence of medially and laterally posted orthotics. *Physical therapy in sport*, 4, 34-39.

Withrow, T.J., Huston. L.J., Wojtys. E.M. et al. (2006). The effect of an impulsive knee valgus moment on in vitro relative ACL strain during a simulated jump landing. *Clinical Biomechanics*, 21, 977–83.

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