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# KINEMATIC CHANGES IN A DANCE JUMP LANDING DUE TO DIFFERENT SHOES

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## SUMMARY
The landing mechanisms of a basic dance jump, known as a sauté, have not been fully explored and the effect of shoe design on landing mechanisms is unknown. This study used 3D motion analysis to explore sagittal plane kinematic differences in a dance jump landing as a result of wearing jazz shoes. Jazz shoe design significantly affected metatarsophalangeal and midfoot motion, suggesting a reduced capacity for impact attenuation through eccentric control and passive means. Greater ankle dorsiflexion was found in all shoes compared to barefoot. No significant difference was found for knee flexion, although the large peak knee flexion angle in all shoe conditions was identified as a potential injury risk factor. No significant affect of the jazz shoes was found at the hip. Further exploration of the kinetic differences will shed light on the landing strategies utilized by dancers to reduce impact on the lower limb.

## INTRODUCTION
A key dance skill is jumping. The ability to jump high whilst conveying ease of movement and weightlessness is an important component of the skill. The constraints of dance technique dictate the body position and alignment throughout the movement and require jump landings to be quiet and controlled. A quiet landing is thought to be facilitated through eccentric control of metatarsophalangeal dorsiflexion, ankle dorsiflexion, knee flexion and hip flexion. The common instruction to dancers is to "roll through the balls of the feet" and to "lift up when landing" to emphasise the eccentric control of the landing and appearance of weightlessness.

Research on the effect of footwear on gait has alluded to the importance of footfall technique as a contributing factor to leg stiffness, muscle recruitment and potentially, injury risk. The effect of footwear design on the restriction or enhancement of dance movement is a relatively uncharted area of research [1] despite being identified as a risk factor for injury [2]. Several studies have investigated the effect of dance footwear on jump landings, finding greater ankle plantarflexion in high heeled shoes [3] and higher loading rates in pointe shoes[4].

Investigation of the interaction between dance shoe designs and the rigour of dance jump landing technique can assist with identifying potential variables which increase injury risk. The aim of this study was to investigate the effect of various jazz shoe designs on sagittal plane landing kinematics of the lower limb.

## METHODS
Sixteen female dancers (mean age: 25 ± 5.9 years, mean mass: 55.9 ± 7.4 kg) volunteered for the study. All participants were required to have attained a minimum of Intermediate standard according to the Royal Academy of Dance Syllabus (RAD) or equivalent to ensure consistent and proficient technique execution. Dancers were excluded if they had a current injury that reduced their class or performance participation. All participants gave informed consent and the study was approved by the University of Sydney Human Research Ethics Committee.

Five shoe conditions were examined: a high-heeled court shoe; three split-sole (separate forefoot and rearfoot outsole) design shoes of varying outsole thickness, ranging from a thin, leather-soled slipper to a robust sneaker design; and the barefoot condition as a control.

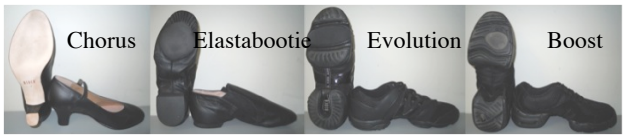


**Figure 1:** Shoe conditions (L-R): High heeled court shoe (Chorus), split-soled jazz shoes (Elastabootie, Evolution dance sneaker, and Boost dance sneaker).

The participants were instructed to perform eight sautés in second position (feet hip-width apart and lower limbs with maximal external rotation) with one foot on each force plate. The task was performed to the RAD Grade One music to control the tempo. The dancers were not allowed to use their arms for assistance during the jumps and were instructed to keep their hands on their waist throughout the task. A 14 - camera motion analysis system captured the movement of 35 retro-reflective markers placed on the pelvis and lower limbs. Markers were placed on the shoes in the corresponding position to palpated bony landmarks on the foot. Orthogonal axes were embedded in the pelvis, thigh, shank, rearfoot and forefoot segments. Joint coordinate systems were constructed for the toe, midfoot, ankle, knee and hip, according to International Society of Biomechanics standards [5]. Data during stance phase were normalised to 100% from toe-strike to toe-off. The landing phase was identified as the first 50% of stance phase.

## RESULTS AND DISCUSSION
The jazz shoe designs did not have a significant effect on hip or knee flexion/extension during landing. All shoe

conditions displayed peak knee flexion angles larger than 60º. Large knee flexion angles >30º during weight-bearing have previously been associated with an increase risk of pain and injury [6, 7, 8, 9].

Ankle dorsiflexion was greater in all shoe conditions compared to barefoot from 20% to 80% of stance phase. The sneaker designs of the Evolution and Boost had greater plantarflexion at initial ground contact. The Chorus shoe had a greater amount of dosiflexion compared to all other shoes in the initial 15% of stance phase.

At the midfoot, the barefoot condition displayed significantly greater plantarflexion angles in the first 20% of stance phase, but greater dorsiflexion from 30-85% of stance. This suggests the barefoot landings are able to dissipate much of the impact through midfoot dorsiflexion.

The design of the Chorus shoes, Evolution and Boost jazz sneakers significantly reduced the amount of dorsiflexion occurring in the first 5% of stance phase compared to barefoot. From 20 to 80% of stance phase all shoe conditions displayed more MPJ plantarflexion than barefoot. The thinner outsole of the Elastabootie may potentially allow a greater range of dorsiflexion at the MPJ.

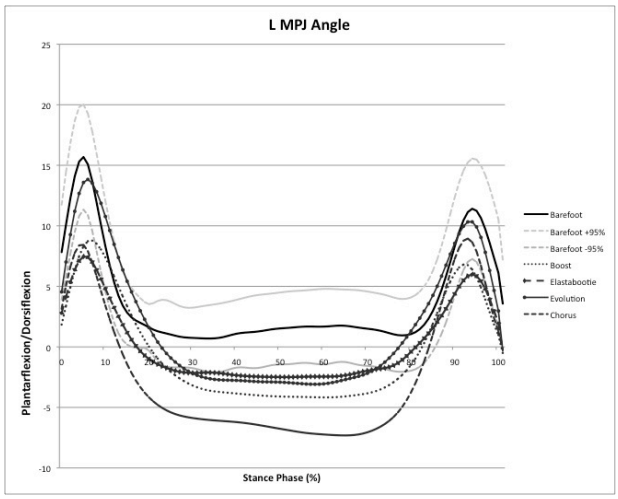


**Figure 2:** MPJ angle of dorsiflexion/plantarflexion from toe strike to toe off.

## CONCLUSIONS

Wearing jazz shoes reduced the amount of midfoot motion and MPJ dorsiflexion which suggests a potential reduction in impact attenuation capacity at the foot. Impact attenuation could therefore be required to occur further up the body.

Although jazz shoe design was not found to significantly affect knee flexion angles, the large flexion angles will place a great amount of force on the structures in the knee [6, 7, 8, 9] during jump landings increasing the risk of knee pain and injury. Although the jazz sneaker designs have greater cushioning, the knees appear to still bear a large proportion of the impact attenuation. The emphasis on quiet landings may also have implications on the joint stiffness of the lower limbs.

Kinematic and kinetic analyses will provide further information on the landing strategies utilised in the lower limb. Of great interest are the mechanisms by which the dancers control the jump landings and how the shoe conditions will influence the landing technique. The landing strategies could shed light on potential injury factors and assist with more informed shoe selection.

## ACKNOWLEDGEMENTS

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## REFERENCES

1. Fong Yan, A., et al., Effect of footwear on dancers: A systematic review. *J Dance Med Sci*. **15**(2):86-92,2011
2. Bejjani, F.J., Occupational biomechanics of athletes and dancers: a comparative approach. *Clin Pod Med Surg*. **4**(3):671-711, 1987.
3. Liederbach, M., The effect of shoe heel height and floor incline on the biomechanics of landing from a single leg jump in elite female dancers, in Department of Environmental Health Sciences, Program in Ergonomics and Biomechanics, 2008, New York University: New York.
4. Chockley, C., Ground reaction force comparison between jumps landing on the full foot and jumps landing en pointe in ballet dancers. *J Dance Med Sci*. **12**(1):5-8, 2008.
5. Wu, G., ISB Letter to the Editor. *J Biomech*. **35**:543-548, 2000.
6. Hains, K., Biomechanical implications of step bench heights. *Strength Cond Coach*. **5**:8-12, 1997.
7. Urquhart, M.W., et al., Meniscal injuries in the adult. In: DeLee J.C., and Drez D.D., editors. *DeLee and Drez's Orthopaedic Sports Medicine Principles and Practice*. 2nd ed. Philadelphia (PA): Elsevier Science, 2003.
8. Markolf, K.L., et al., Effects of combined knee loadings on posterior cruciate ligament force generation. *J Orthop Res*. **14**:633-638, 1996.
9. Besier, T.F., et al., Patellofemoral joint contact area increases with knee flexion and weight-bearing. *J Orthop Res*. **23**:345-350, 2005.