

# IMPACT FORCES DURING BALLET: IMPLICATIONS FOR INJURY

<sup>1</sup> Rhonda Boros and <sup>2</sup>Lindsey Skelton

<sup>1</sup>Biomechanics Lab, Health, Exercise & Sport Sciences, Texas Tech University

<sup>2</sup>Department of Sociology, Anthropology, and Social Work, Texas Tech University

email: [RL.BOROS@TTU.EDU](mailto:RL.BOROS@TTU.EDU), web: <http://www.hess.ttu.edu/rboros>

## INTRODUCTION

Pre-professional high school and professional ballet dancers are at extremely high risk for mild and severe lower extremity injury [1,2]. A 26 to 51% lifetime injury prevalence in collegiate and professional dancers has been reported [1]. This high injury risk is cause for concern, as the study of ballet is typically initiated at an extremely young age, and young dancers spend a great deal of time in the dance hall training and practicing [1].

Dance related injuries in ballet have often been associated with high magnitude landing impacts. However, there is a lack of scientific research describing the ground reaction forces associated with common ballet skills [1,3], and only a few select skills, including the grand plie, demi plie, passé, grand jete and aerobic dance have been analyzed biomechanically to any extent [1,4,5,6,7]. Comparative ground reaction forces during isolated ballet skills versus skills performed as part of a dance routine are also lacking.

The main purposes of this study, therefore, were to 1) determine the relative ground reaction forces during the performance of five basic ballet skills (grand plie, arabesque, cabriole, changement, entrecht) and compare them with those of more common locomotion skills (vertical jump, hop, walk, jog); and 2) determine any changes in ground reaction forces that occur when the ballet skills are performed as part of a dance routine.

## METHODS

Six female ballet dancers from pre-professional and collegiate dance programs in the Lubbock, TX area, (mean $\pm$ -SD age 19.7 $\pm$ -2.7yr, mass 60.8 $\pm$ -5.0kg, height 1.642 $\pm$ -0.025m) participated as subjects. Each subject was informed of the study purpose and signed an informed consent prior to participation.

Subjects wore their own ballet slippers for all trials. Two AMTI force plates sampling at 1000 Hz were used to determine body mass normalized ground reaction forces (N/kg body mass).

Following an individual warm-up, each subject performed five counter-movement vertical jumps (CMJ) starting and landing on the same force plate. To control arm swing hands were clasped behind the head. Following the jump trials, two trials each of hopping, walking, and jogging were performed. Four trials each of the ballet skills (grand plie, changement, entrecht, arabesque, and cabriole) were subsequently performed for comparison with the more everyday locomotion skills.

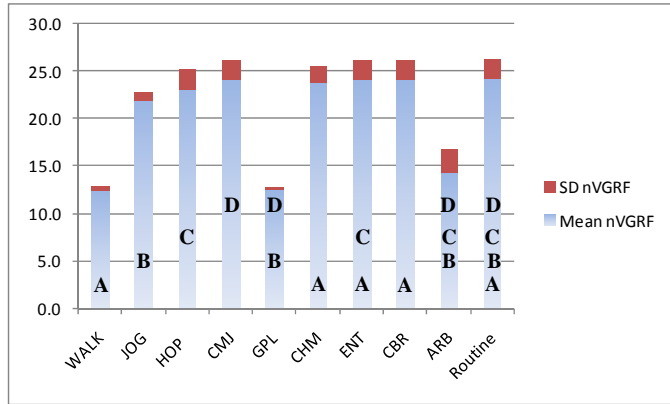
Finally, dancers performed a dance routine consisting of two changements, two entrechts (all leaving and landing on a single force plate), followed by two balonetes moving forward off the plate, followed by one pique arabesque into a one step tour jete with the final landing occurring back on the original force place. The main purpose of this routine was to allow the comparison of ground reaction forces incurred during dance skills performed in isolation with the same or similar skills performed as part of a dance routine. Statistical comparisons were made via paired t-tests, with a significance level set at 0.05.

## RESULTS AND DISCUSSION

Normalized vertical ground reaction forces (nVGRF) were similar to those previously reported for aerobic dance [6,7] and traveling leaps [4,5,6]. Mean and standard deviation results for the locomotion and dance trials are presented in Figure 1, and statistically significant differences ( $p < 0.05$ ) between the locomotion and ballet skills are noted.

During the CMJ, dancers were instructed to jump as high as possible, thus attempting to develop a

maximal effort impulse to propel their bodies vertically in the air. Landing nVGRF of the entrecht and cabriole were similar to those of the CMJ, suggesting that the dancers needed to create as much vertical force as possible (near maximum effort perhaps) to achieve the desired image and technical characteristics of the skills.



**Figure 1:** nVGRF (N/kg) during locomotion and ballet skills. Letters denote significant differences ( $p < 0.05$ ) between locomotion and ballet skills.

The change ment impact forces were similar to those of hopping, perhaps demonstrating that the dancers only needed to generate and absorb moderate amounts of force to perform this skill properly. Arabesque and grand plie nVGRF were similar to those of walking, suggesting that these forces are of low impact and hence deliver minimal stress to the lower extremity.

The highest ground reaction forces occurred during the dance routine (~2.3BW). An interesting finding was that the peak forces during the dance routine were experienced during the consecutive change ments and entrechts, rather than during the final tour jete. This result is somewhat unexpected, as the tour jete involved a greater horizontal distance traveled and thus would be expected to result in a greater impact peak [4,5]. A possible explanation for our observation is that the performance of the four sequential change ment and entrecht jumps required stiffer lower extremity control compared with the same skills in isolation, resulting in relatively larger nVGRF. The final tour jete, in contrast, was the final landing in the routine after which the dancers simply stepped through and off the plate. Had the dancers been required to stick this final landing, the impact forces would have likely been much greater. This latest result has huge implications for injury considering the incredible

number of hours young ballerinas spend training and perfecting their technique and performance.

## CONCLUSIONS

Results of the present study demonstrate that many ground impact forces experienced during ballet jumps are statistically significantly greater than those of measured walking, hopping and even jogging locomotor patterns. Repeated or sequenced contacts in dance were shown to produce greater impact forces compared with isolated skills. Considering pre-professional high school ballet dancers have been reported to train over five hours a day [1], there is some cause for concern that these repeated impacts may play a critical role in acute and chronic lower extremity injury.

The present study did not account for the foot contact area absorbing the impacts nor joint kinematics associated with these skill performances. Considering female ballet landings are performed primarily en pointe (i.e., on the toes) [8], further research is needed to determine the true foot pressures and lower extremity joint forces and moments realized during isolated and sequential ballet landing impacts.

## REFERENCES

1. Hincapie CA, et al. *Arch Phys Med Rehabil*, **89**, 1819-1829, 2008.
2. Bronner S, et al. *Am J Sports Med*, **31**, 365-373, 2003.
3. Tuckman AS, et al. *Foot & Ankle*, **13**, 220-223, 1992.
4. Simpson KJ and Kanter L. *Med Sci Sports Exerc*, **29**, 916-927, 1997.
5. Simpson KJ and Pettit M. *Med Sci Sports Exerc*, **29**, 928-936, 1997.
6. Michaud TJ, et al. *J. Sports Med Physical Fit*, **33**, 359-366, 1993.
7. Ricard MD and Veatch S. *J Applied Biomech*, **10**, 14-27, 1994.
8. Miller CD, et al. *Foot & Ankle*, **11**, 97-100, 1990.

## ACKNOWLEDGEMENTS

We would like to thank the student assistants in the Biomechanics Lab at Texas Tech, especially Brent Carter for his ballet expertise and assistance with data collection and processing.