GROUND REACTION FORCES DURING "POINTE" IN BALLET

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The purpose of this study was to investigate the differences in ground reaction forces between right and left leg during pointe. Fifteen ballet dancers who have no lower limb injury participated in this study. Eight infrared cameras (Qualisys, Sweden) and two force plates (Kistler, Switzerland) were used for a three dimensional motion analysis. Ballet dancers were asked to perform 10 trials of "demi-plie en pointe". The results showed significant differences in vertical ground reaction forces between right and left leg at maximum ankle extension (E3, p<0.5). Also, significant differences were found in the range of COP for both right and left leg during P2 and P3. The findings indicated that ballet dancers showed greater changes of COP displacement in left leg compared to right leg during pointe.

KEY WORDS: Ballet, Biomechanics, COP, GRF, Pointe.

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INTRODUCTION: It has been known that ankle stability in ballet dance is complex research topic in the area of biomechanics. Especially, pointe is one of difficult techniques as a dancer supports the body on a small area of the platform of toe shoes (Kwon, 2001; Sin & Lee, 2008). Therefore, a perfect control of the extrinsic muscles across ankle and knee joints may play an important key component for successful motion. Therefore, the purpose of this study was to quantify how ballet dancers balance the body during pointe through the analysis of ground reaction forces.

METHODS: Fifteen classical ballet dancers (height: 160.86±4.18 cm, mass: 48.42±4.11 kg, age: 21.13±1.06 years, career: 7.3±1.4 year) participated in this study. Dancers with their own leotard and toe shoes performed ten trials of "demi-plie en pointe". Dancers placed each foot on a separated force plate and they were asked to perform the trial with a sign of data collection. Eight infrared cameras (Qualisys, Sweden) with a sampling rate of 100Hz and two force plates (Kistler, Switzerland) with a sampling rate of 1000Hz were used. Visual 3D program (C-motion, USA) was used to calculate variables. Data was calculated at four events including three phases as illustrated in Figure 1 (E1: maximum knee extension, E2: maximum knee flexion, E3: maximum ankle extension, E4: End of movement (1 second after E3), P1: E1~E2, P2: E2~E3, P3: E3~E4). Paired t-test with an alpha level of 0.05 using SPSS version 19.0(IBM, USA) was applied to find the differences in ground reaction forces between right and left leg.

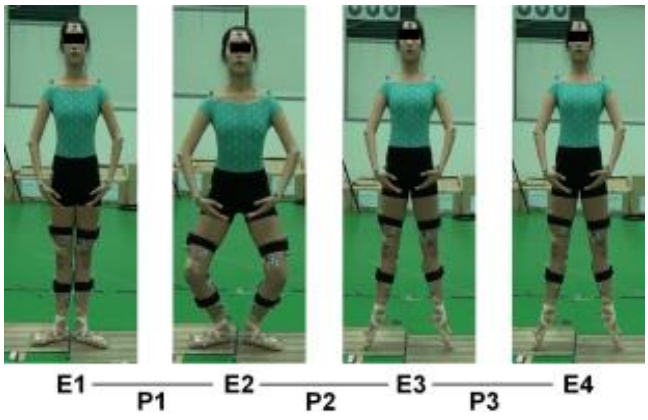

Figure 1: Definition of Events & Phases during "demi-plie en pointe"

RESULTS: Figure 2 shows that dancers generated greater vertical ground reaction forces from right leg at E3 (maximum ankle extension) compared to left leg (Right leg: 5.57±0.96Nm/kg vs. Left leg: 5.13±0.60Nm/kg, P=0.043, Table 1).

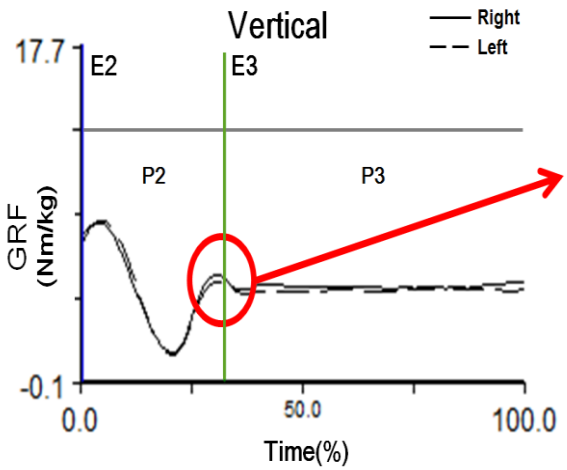

Figure 2: Difference in vertical ground reaction force between left and right leg at E3

Table 1: Vertical Ground Reaction Forces (Nm/kg)

	Event 2		Event 3	
	Right	Left	Right	Left
Mean±SD	7.56±1.34	7.28±1.29	5.57±0.96	5.13±0.60
T(P-value)	1.302(0.214)		2.221(0.043*)	

* indicates a significant difference between right and left leg

Figure 3 also shows the differences in the range of COP between right and left leg at P2 and P3 (P<0.05). The findings indicated that participants showed greater range of COP on left leg in anterior-posterior and medial-lateral directions compared to right leg during pointe.

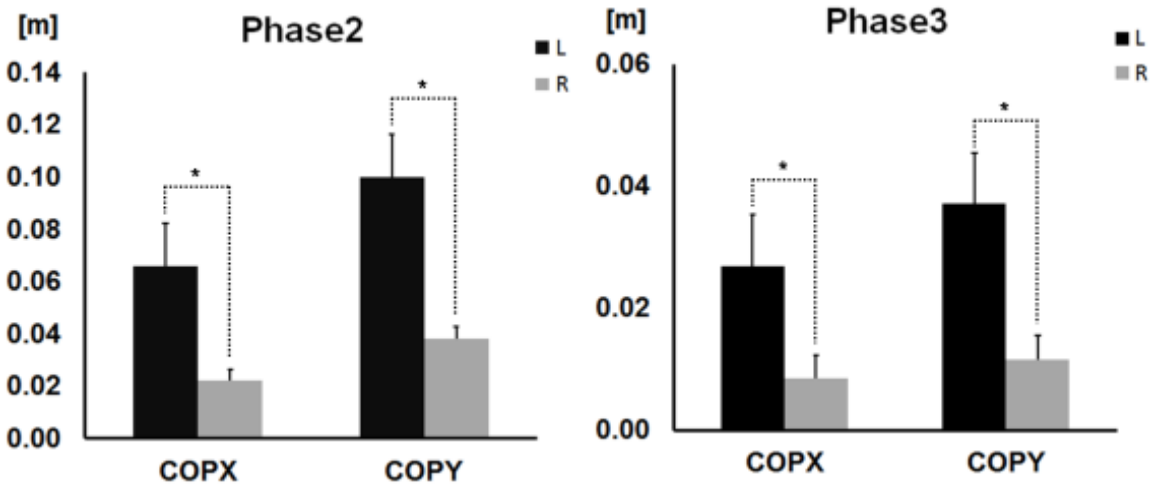

Figure 3: COP range (X: medial-lateral, Y: anterior-posterior, R: right foot, L: left foot)

DISCUSSION: The foot and ankle were the most frequently injured part of body in dancers (Garrick & Requan, 1993; O'Malley, Hamilton, & Munyak, 1996). A previous study investigated injury mechanism of the lower extremity correlated with dancing techniques, especially in ballet (Schon & Weinfeld, 1996). Ballet dancers have to perform superior

balance and stability compared to other types of dance as they play more challenging technique such pointe (Lin, Su, & Wu, 2005). Particularly, this motion requires ballet dancers to bear intensive loading at the extreme range of the joint in the lower leg with a small base of support. Such a maneuver cause high stress on the medial structure of the foot and ankle, which could lead to chronic joint injuries (Hardaker, 1989). Therefore, an optimal performance of pointe in ballet should meet high level of body control with a good stability of the lower extremity in terms of injury prevention and aesthetic component of ballet. However, to date, there was limited information on fundamental movement in ballet such as pointe.
Based on the findings of this study, dancers more rely on the function of right leg compared to left leg from P2 to P3 as there were greater vertical ground forces on right leg. In addition, our findings indicated that a greater range of COP on left leg compared to right leg was shown indicating less stability on left leg during pointe. It is assumed that dancers used right leg or dominant leg as a leading leg with more variations on left leg during the motion. Also, it indicates that there was a certain level of asymmetric loading existing when the toe plays a major supporter at the end of pointe. This asymmetric loading at the lower leg could be depending on the level of skill in dancers.

CONCLUSION: Further biomechanical study associated with the function of the joints of lower extremity regarding posture control and balance would be required.

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