TEMPORAL, FORCE AND POSTURAL ANALYSIS OF RELEVÉ EN POINTE IN NOVICE AND INTERMEDIATE DANCERS

Gabriella Penitente[1], Melissa J. Hull[1] , William A. Sands[2]

Academy of Sport and Physical Activity, Sheffield Hallam University, UK[1]

Exercise & Sport Science, East Tennessee State University, Johnson City, USA[2]

This study compares temporal, vertical force and postural sway variables between novice and intermediate dancers performing *echappé relevé en pointe* (a); to determine the influence of experience on intra-individual variability on the aforementioned performance parameters (b). Six trials performed by four novice and four intermediate dancers on a force platform were analysed. Large differences between the two groups of dancers were observed in the duration of the transition phase from the *plié* to *the en pointe* and in the length of sway path of the CoP during the *en pointe* phase. High loading rate was recorded when landing *en pointe*. Both groups of dancers showed a relatively large rate of intra-individual variability that can be seen as a task-relevant learning facilitator factor.

KEY WORDS: ballet, dance, kinetics, relevé, on pointe.

INTRODUCTION: To master the ability to dance on pointe is an important aspect of a ballerina`s training. According to the International Association for Dance Medicine and Science (IADMS), before starting pointe work a ballerina should have at least four years of demi-pointe experience (Weiss, Rist & Grossman, 2009). On pointe techniques include *relevé*, poses, pirouettes, hops and jumps in which ballerinas aim to appear elegant and effortless. The efficiency of the pointework depends upon both biomechanical and artistic elements. The critical aspects of the pointework are body alignment and smooth transitions to and from the on pointe position. One of the fundamental transition techniques is the *relevé en pointe*, in which the dancer, starting from a turn-out position[1], shifts from a flat-foot stand to a toe stand. This rising action begins and ends in a plié (small knee bend).
High incidence of ankle injuries (Conti & Stone, 1995), as well as feet morphological alterations commonly associated with dancing on pointe (Miller et al., 1975), has been to date the main rationale behind the biomechanics research on the *relevé en pointe* (Lin, Su and Wu, 2005; Dozzi & Winter, 1993 cited in Krasnow et.al. 2011). Less research has been conducted into the performance components such as rhythm, grace and balance, which characterize this fundamental ballet technique. Thus, the first aim of this study was to compare temporal parameters, vertical force variables and postural sway between novice and intermediate dancers performing *echappé relevé en pointe*. Moreover, as it has been recognised that consistency is a measure of learning (Wilson, 2009), the second aim was to determine the influence of experience on intra-individual variability across repeated trials.

METHODS: Eight female recreational classic dancers volunteered for the study, four were novice dancers (19.5 ± 7 yrs; 59.2 ± 9.8 kg; 165 ± 4.1 cm) with less than one year experience of dancing on pointe; four were intermediate dancers (24.75 ± 6.2 yrs; 57.2 ± 9.9 kg; 166.2 ± 3.3 cm) with three to five years experience of dancing on pointe. Following a self-selected warm-up routine, each dancer performed three trials of five consecutive *echappé relevé* from 5th position, to 2nd position on pointe (Figure 1). For consistency, only two *echappé relevé* per trial were selected, and a total of six trials per dancer were used for the analysis. The evaluation of each *echappé* focussed on the following phases: plié to the on pointe transition phase (from take-off after the plié to impact on pointe), on pointe phase (from impact to take-off on pointe) and on pointe to plié transition phase (from take-off on pointe to landing in plié).

Force data were collected at 800 Hz from a force plate (Kistler, 9281CA, Winterrthur, Switlzerland). Two genlocked cameras (NV-GS400, Panasonic) recorded the movement from the sagittal and frontal plane at 50 Hz. Video clips were used for quality control.
The durations of the three phases described above were obtained from the force-time traces.

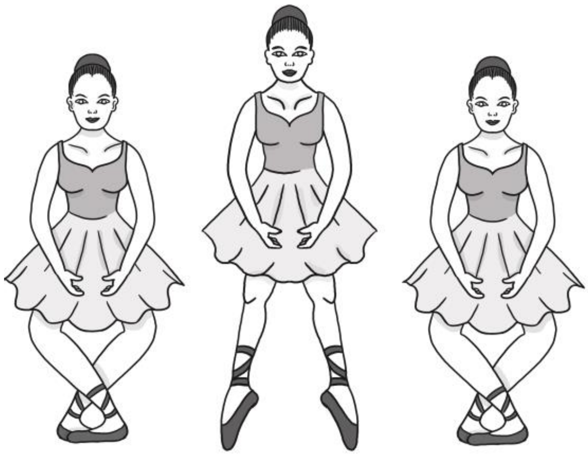

Figure 1. Echappé relevé

Ground reaction force variables included peak vertical force and average loading rate (LR) at impact on pointe. Average loading rate was calculated between 20 and 80% of the time to impact peak (Milner et al., 2006). Force data were normalized to body weight (BW) to allow comparisons between participants. The length of the sway path and maximal range of the center of pressure (CoP) displacement in the anterior-posterior (A-P) and the medio-lateral (M-L) direction during the on pointe phase were used to measure the postural sway.
Statistical analysis was performed using SPSS 19.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics included mean and standard deviation. The coefficient of variation (%CV) was calculated to assess the relative intra-individual variability of each variable for the novice and intermediate dancers across the eight trials (Mullineaux, 2000). Differences in the temporal, vertical GRF, postural sway variables and variability measures between the two groups were assessed using Mann Whitney tests ($p < 0.05$). Effect sizes (ES), computed as Cohen`s d (Cohen, 1988) were used to quantify the size of the differences between the two groups of dancers.

RESULTS Although the Mann-Whitney test failed to detect any statistically significant difference, results in Table 1 show several medium and large differences in the biomechanical variables between the two groups. The duration of the transition phase from plié to on pointe and the length of the path of the CoP had a large ES, 1.3 and 1.2, respectively. The loading rate when landing on pointe (ES = 0.7), the A-P (ES = 0.7) and M-L (ES = 0.5) maximal range of the CoP during the on pointe phase showed medium effect size differences between novice and intermediate dancers.
Medium and large differences were found in the intra-individual variability measured over six repeated trials (Table 2). The variability of the duration of the two transition phases, before and after the on pointe phase, showed a large difference between the two groups (ES of 1.3 and 1.5, respectively). The variability of the duration of the on pointe phase and the M-L maximal range of the CoP displacement during the on pointe phase showed medium size differences between intermediate and novice dancers (ES of 0.5 and 0.4, respectively).

Table 1: Descriptive statistics of kinetic variables of the *echappé en pointe*

	Novice (n=4)	Intermediate (n=4)
	Mn (SD)	Mn (SD)
Temporal par		
Plié to En pointe (s)**	0.09 (0.01)	0.07 (0.03)
En pointe (s)	0.44 (0.08)	0.44 (0.06)
En pointe to Plié (s)	0.06 (0.01)	0.07 (0.02)
Vertical GRF		
Imp Force (BW)	1.9 (0.4)	1.9 (0.5)
LR (BWs^{-1})*	57.0 (21.5)	41.5 (21.3)
Postural sway		
Sway length (cm)**	62.4 (8.4)	53.1 (7.7)
Range A-P (cm)*	3.5 (0.7)	3.1 (0.7)
Range M-L (cm)*	28.5 (6.1)	25.8 (3.7)

ł Mann- Whitney test sign (p<.05) * Medium ES, **Large ES

Table 2: Descriptive statistics of intra-individual variability across six trials of *echappé en pointe*

	Novice (n-4)	Intermediate (n=4)
	Mn (SD) %	Mn (SD) %
Temporal par		
Plié to En pointe**	26 (14)	47 (20)
En pointe*	11 (4)	8 (5)
En pointe to Plié **	29 (10)	15 (8)
Vertical GRF		
Imp Force	17 (9)	17 (7)
LR	55 (32)	60 (22)
Postural sway		
Sway length	15 (5)	16 (6)
Range A-P	44 (16)	43 (5)
Range M-L*	32 (16)	27 (9)

DISCUSSION: The present study compared the kinetic pattern of the *echappé relevé en pointe* performed by intermediate and novice dancers. This is a fundamental movement technique commonly used by ballerinas to transit from and to the on pointe position. Rhythm, grace and balance, performance components that characterize a competent performance were evaluated analysing temporal, impact force and postural sway variables.

This study investigated the performance of recreational dancers, with a relatively modest amount of weekly training on pointe, which makes their learning process slower when compared to professional or academy dancers. Taking this into account, it was not surprising that differences between the two groups did not reach the statistical significance.

Nevertheless, inspection of the effect size indicators showed that the intermediate dancers possessed a more controlled and coordinated performance (Table 1).

For this group the two transition phases had, in fact, the same average duration. Novice dancers had a longer first transition phase from the plié to the on pointe position (0.09s) than the intermediate dancers, which may indicate an excessive push action from the plié to reach the on pointe position. In contrast, the second transition phase from on pointe to plié, was shorter (0.06) than the intermediate dancers, it may be caused by a limited ability to control the eccentric (downward) phase of the movement. An excessive push from the plié may also explain the following higher loading rate recorded at the impact on pointe for the novice with respect to the intermediate dancers (N: 57 ± 21.5 BWs^{-1} I: 41.5 ± 21.3 BWs^{-1}). Moreover, if a large loading rate is a major injury factor, it is worthwhile to note that the values found for the novice dancers were comparable to those reported in literature for running (shod run: 83.9 ± 4.54 $BW \cdot s^{-1}$; barefoot run: 69.9 ± 4.77 $BW \cdot s^{-1}$, Cheung, 2013) and for a hop jump from a height of 6 cm (56.99 $BW \cdot s^{-1}$, Ricard & Veatch, 1994).

The posture analysis also revealed that novice dancers, after about six months of pointework, were able to perform the *relevé en pointe* without the support of the barre, however they did not have a similar ability to control balance as the intermediate dancers. The three postural sway variables analysed consistently showed that intermediate dancers were more stable than novice dancers during the *en pointe* phase. Intermediate dancers had a shorter sway path length (N: 62.4 ± 8.4 cm; I: 53.2 ± 7.7 cm), and a smaller maximal range of the CoP in both A-P (N: 3.5 ± 0.7 cm; I: 3.1 ± 0.7 cm) and M-L (N: 28.5 ± 6.1 cm; I: 25.8 ± 3.7 cm) directions.

Results show that for a number of variables, intermediate dancers had an average intra-individual variability higher or similar to the novice dancers (Table 2). A systematically more consistent performance across multiple trials could be expected from the intermediate dancers; however, it has been recognised that motor variability in the baseline period of skill acquisition is not simply `noise`, but a natural exploration strategy that facilitates learning of specific skills (Wu et al., 2014). Moreover, large intra-individual variability across multiple trials performed by highly skilled dancers has been previously documented by Chatfield (2003).

CONCLUSION: Differences in temporal, force and postural variables between novice and intermediate dancers performing *relevé en pointe* may suggest that some caution should be used with novice dancers in transferring this movement from the barre to the center. Specific strength and proprioception exercises should be embedded in the training program of recreational ballerinas.

Further investigations comparing recreation and academy dancers are necessary to better understand the performance strategies and motor skill acquisition process involved in classic ballet.

REFERENCES:

Chatfield S. (2003). Variability of electromyographic and kinematic measurement in dance medicine and science research. *Journal of Dance Medicine and Science*, 2, 42-48.

Cheung R.T.H. (2013). Landing pattern and vertical loading rates during shod and barefoot running in habitual shod runners. *31st International Symposium on Biomechanics in Sports (ISBS 2013)*

Cohen, J. (1988). Statistical power analysis for the behavioral sciences. (2nd ed.) Hillsdale, NJ:Erlbaum.

Conti, S.F. & Stone, D.A. (1995). In Rehabilitation of fractures and sprains of the foot. *Rehabilitation of the foot and ankle*. R. Hurley, ed. 127-144.

Lin,C., Su, F & Wu, H.(2005). Ankle biomechanics of dancers in relevé en pointe dance. *Research in Sports Medicine*, 13, 23-35.

Miller, E.H., Schneider, H.J., Bronson, J.L. & McLainid,D. (1975). A new consideration in athletic injuries: the classic ballet dancer. *Clinical Orthopaedics and Related Research*, (111) 181-191.

Milner,C.E.,Ferber, R.,Pollard, C.D., Hamill J. & Davis I.S. (2006). Biomechanical factors associated with tibial stress fracture in female runners. *Medicine and Science in Sport and Exercise*, 38(2), 323-328.

Mullineaux,D. (2000). Methods for quantifying the variability in data. *18th International Symposium on Biomechanics in Sports (ISBS 2000).*

Ricard, M.D., Veatch S. (1994). Effect of running speed and aerobic dance jump height on vertical ground reaction forces. Journal of Applied Biomechanics, 10, 14-27

Weiss, D.S., Rist, M.D. & Grossman G. (2009). When can I start pointe work? Guidelines for initiating pointe training. *Journal of Dance Medicine and Science*, 13(3), 90-92.

Wilson, M.(2009). Applying biomechanic research in the dance studio. *The IADMS Bulletin for Teachers*, 1(2),11-13.

Wu, H., Miyamoto, Y., Gonzales-Castro, L.N., Olveczky, B.P. & Smith, M.A. (2014).Nature Neuroscience, 17, 312-321.

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