THE INFLUENCE OF PRECEDING MOVEMENTS IN THE PERFORMANCE OF BALLET JUMPS

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The purpose of this study was to gain more insights about the individual technique used in the performance of ballet jumps and determine the influence of preceding movements in the efficiency of its performance. Seven female ballet students participate voluntarily in the study. Ground reaction forces were measured using a Bertec force plate. A triaxial accelerometer was placed at the low back of the subject on the skin surface, approximately at the height of the centre of mass. Results suggest that generally, a positive influence from preceding movements was observed in the performance of the selected jumps. Jumps preceded by only one movement, show a tendency to an increase in the reached height. Due to an immature technique of performance, our ballet students did not use appropriately preceding movements to potentiate the subsequent jumps.

KEYWORDS: Ballet, Jumps, SSC.

INTRODUCTION: Classical ballet and modern dance have been shown to be as physically demanding as many team sports (basketball, soccer, football, and volleyball) and very jump-intensive (Nicholas, 1975). Due to the nature of their movements, which involves unusual amplitudes of movement, unusual joint positions, and muscular efforts with excessive impact forces, it is well accepted the significant degeneration of anatomical structures, like bone tissue, tendons and ligaments (Nicholas, 1975; Simpson & Kanter, 1997; Simpson & Pettit, 1997). According to Liederbach et al., (2006), classical ballet dancers perform more than 200 jumps per 1.5-hour daily technique class, more than half of which involve single-leg landing. Despite these, according to some author's the incidence of injuries among dancers is much lower than that among team sport athletes (Orishimo, Kremenic, Pappas, Hagins., & Liederbach, 2009). Several factors unique to dance may be partially responsible for the low injury rates in this population, like technique and intensive training from a young age. Dancers are trained to land with the lower extremities near full extension, with a vertical spine and with maximum use of plantar flexion at initial contact. It is expected that dancers land on the plantar surface of their phalanges and metatarsal heads and immediately roll through their feet, with eccentric control to achieve a quiet heel touchdown and controlling the alignment of the center of the patella directly over the second ray of the foot, trying to dissipate landing forces and to achieve the desired aesthetics of a smooth landing. The goal of the present study was to gain more insights about the individual technique used in ballet jumps, namely the influence that preceding movements can be in the efficiency of its performance. This was done through comparison of kinematical and kinetic parameters in isolated ballet jumps and sequences of movements preceding the same jumps.

METHOD: Seven female ballet students (19.1± 4.1years old, 55.9± kg, 165.0±3.0 cm), with more than ten years of daily practice in classical ballet participated voluntarily in the study. The subjects were fully informed about the purpose, procedures and risks associated with the study and gave their written consent after being informed. The study was approved by the Ethics Committee of the University. None of the dancers present, until the moment, any kind of injury that could influence the performance of the jumps. After a short warm-up, which was individually selected by the ballet dancers, subjects were familiarized with the experimental procedures for data collection. Ground reaction forces were measured using a Bertec force plate (4060-15), with a sample frequency of 1000Hz. Additionally a triaxial accelerometer was placed at the low back of the subject on the skin surface approximately at the height of the centre of mass (Biopac, type TDS109, sensitivity 40 mV/g, range ±50g). Both force-plate and accelerometer signals were sampled at 1000 Hz. After amplifying, all analog signals were converted to digital signals using the 16 bit A/D converter from Biopac. Elementary ballet jumps as well as small sequences of these elementary jumps were selected for the study: Jump 1- squat jump (figure 1 a); Jump 2- counter movement jump (figure 1 b); Jump 3- *Temps levé* (figure 1 c); Jump 4- *Jeté Temps levé* (figure 1 d); Jump 5- *Assemble* (figure 1 e); Jump 6- *Glissade Assemble* (figure 1 e, preceded by a connection element, the small jump *Glissade*); Jump 7- sequence of eight *Sautés* (8* figure 1 b); Jump 8- sequence of six *Jeté Temps levé* (6* figure 1 d)*;* Jump 9- *Entrechat quatre* (figure 1 f); Jump 10- sequence of six *Entrechat quatre* (6* figure 1 f); Jump 11- *Assemble Entrechat quatre* (figure 1 g). The first and second jumps were performed in first position and legs in turn out position. The take-off and the landing phases of jumps 1, 2, 3, 4, 5 and 11 were performed always in the force plate. In Jump 6 only the landing phase was performed on the force plate. Jump 7 was performed in sets of eight consecutive jumps. Jumps 8 and 10 were performed in sets of six consecutive jumps. Three successful trials were required for each jump or sequences of jumps. Jumps were collected in a random order. The determination of jump pairing for subsequent statistical analysis was based on the assumption of being the same jump, or jumps with similar technical requirements, performed in different sequences or isolated. The following parameters were defined for analysis: **t1**- time interval (s) between the beginning of the movement and the moment of losing contact with the force plate; **t2**- time interval (s) between the beginning of new contact with the force plate, after the aerial phase of the jump, and the end of the movement; **f1**- mean vertical force (F_z) as a function of body weight (BW), exerted in the time interval **t1**; **f2**- mean vertical force (F_z) as a function of BW, exerted in the time interval **t2**; **a1**- mean acceleration (m/s/s) in the time interval **t1**; **a2**- mean acceleration (m/s/s) in the time interval **t2**; **t3**- time duration of the aerial phase (s), and **h**- jump height. Values are presented as means and standard deviations (SD) unless otherwise stated. Non-parametric tests were applied for statistical analysis to compare means between the jump pairs. The value of significance was set at α=0.05.

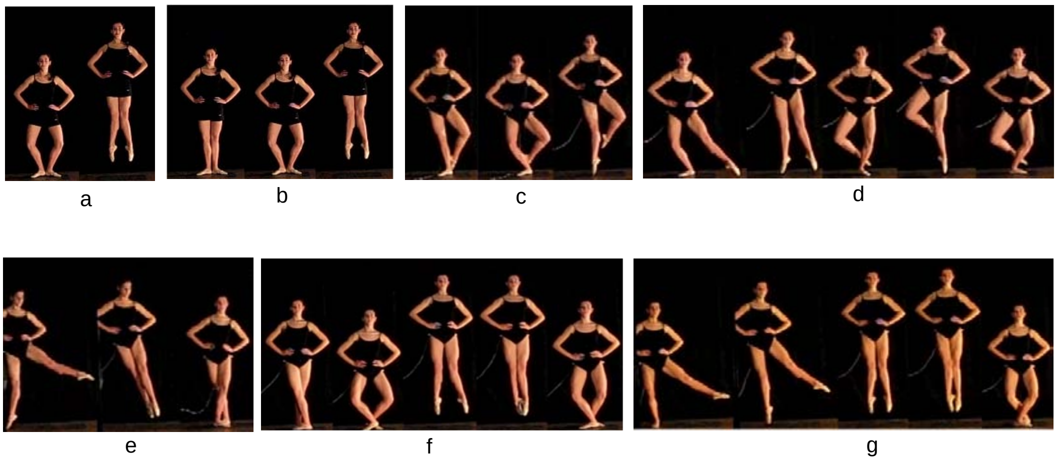

Figure 1. Elementary ballet jumps selected for the study: a) squat jump; b) counter movement jump; c) *Temps levé*; d) *Jeté Temps levé*; e) *Assemble*; f) *Entrechat quatre*; g) *Assemble Entrechat quatre*.

RESULTS: Table 1 presents the average values (±SD) of all the parameters selected for analysis in each jump.

Table 1. Average and SD values for time duration (t1 and t2), F_z force (f1 and f2), acceleration (a1and a2), time duration of the aerial phase (t3), and jump height (h) in all jumps and in all subjects.

Jump	t1 (s)	t2 (s)	F1 (F/BW)	F2 (F/BW)	a1 (m/s/s)	a2 (m/s/s)	t3 (s)	H (cm)
1	0,13±0,02	0,10±0,00	2,62±0,20	2,88±0,46	1,52±0,28	1,79±0,60	0,35±0,00	15.44±1.68
2	0,16±0,02	0,10±0,01	2,70±0,21	2,83±0,32	1,51±0,34	1,58±0,45	0,38±0,02	18.01±2.07
3	0,18±0,14	0,13±0,00	2,05±0,17	2,52±0,25	0,79±0,17	1,47±0,34	0,23±0,02	6.51±1.10
4	0,21±0,47	0,13±0,01	2,43±0,35	2,63±0,25	1,15±0,24	1,50±0,26	0,23±0,04	6.81±1.83
5		0,11±0,02		2,74±0,39		1,77±0,56		
6		0,10±0,01		2,88±0,45		1,81±0,70		
7	0,18±0,02	0,09±0,01	3,48±0,38	3,12±0,45	2,51±0,62	2,42±0,75	0,36±0,03	15.70±2.48
8	0,21±0,03	0,12±0,01	2,66±0,03	2,34±0,21	1,56±0,24	1,25±0,38	0,23±0,02	6.40±1.12
9	0,14±0,01	0,10±0,00	2,94±0,26	3,06±0,26	1,83±0,41	1,92±0,40	0,37±0,02	16.59±1.89
10	0,17±0,02	0,09±0,01	3,58±0,53	3,14±0,39	2,58±0,42	2,22±0,52	0,37±0,03	16.58±2.85
11	0,13±0,01	0,09±0,01	3,36±0,53	3,06±0,36	2,30±0,46	2,02±0,48	0,38±0,04	17.56±3.16

Table 2 presents the p-values for the Wilcoxon test between the jump pairs. We paired jumps 1 and 2; jumps 2 and 7; jumps 2 and 5; jumps 3 and 4; jumps 3 and 8; jumps 4 and 8; jumps 5 and 6; jumps 9 and 11; jumps 9 and 10; and finally jumps 10 and 11.

Table 2. p-values for the Wilcoxon test between jump pairs in time duration (t1 and t2), F_z force (f1 and f2), acceleration (a1and a2), time duration of the aerial phase (t3), and jump height (h).

Jump Pairs	t1	t2	F1	F2	a1	a2	t3	h
1- 2	0,028	0,173	0,345	0,753	0,917	0,463	0,028	0.028
2- 7	0,173	0,028	0,028	0,116	0,046	0,028	0,028	0.028
2- 5		0,917		0,753		0,249		
3- 4	0,173	0,249	0,046	0,345	0,028	0,753	0,917	0.917
3- 8	0,116	0,249	0,028	0,249	0,028	0,917	0,753	0.753
4- 8	0,173	0,463	0,116	0,345	0,075	0,249	0,345	0.345
5- 6		0,075		0,173		0,753		
9- 11	0,115	0,080	0,116	0,917	0,116	0,093	0,173	0.173
9- 10	0,116	0,046	0,046	0,600	0,046	0,075	0,917	0.917
10- 11	0,028	0,141	0,116	0,917	0,046	0,463	0,075	0.075

DISCUSSION: As it possible observe in table 1, the time duration of the aerial phase was significantly higher in jump 2 (counter-movement jump in first position and legs in turn out position), and in this way, the maximal vertical displacement was also observed in this jump. These specific particularities lead us to the concept of stretch-shortening cycle (SSC) (Norman & Komi, 1979). The forced lengthening of an active muscle before allowing it to shorten, leads to an enhanced response during the shortening phase. This potentiation phenomenon is a very common muscle action present in many human movements. In the same way as in the performance of the sportive jumps, ballet jumps follow the same potentiation mechanism of the SSC. Unfortunately, due to the deficient technique used by these ballet students in his performances, the potentiation phenomenon was not always registered in all jumps. Higher values of force (F_z) as a function of BW, in both phases of impulsion and reception, were observed in Jump 10 (a sequence of six *Entrechat quatre*). This jump is a highly demanding jump belonging to the *batterie* exercises in a ballet lesson. During the aerial phase of these jumps, dancers should perform a fast and precise exchange of legs with a controlled and smooth landing. It is also possible to observe that, as expected, in jumps previously preceded by the *Jeté* action (Jumps 4 and 8), the time duration **t1** (time interval between the beginning of the movement and the moment of losing contact with the force plate) was higher. This action involves a sliding of one foot in the ground, during a *plié* movement, to increase the contact time and extend the impulsion phase in order to improve the amplitude and efficiency of the following jump. Unfortunately, this complex action was not well used by our students in the connection to the following jump, reflecting a losing of potentiation and probably of the total energy. Accordingly, this fact can be attenuated with a proper technique and intensive training programs from a young age (Orishimo et al., 2009). These facts can also be observed in table 2. The major number of parameters significantly related was only observed in the jump pairing between jumps 2 and 7. Contrary to the expected, in the other jump pairs the number of parameters significantly different was less marked.

CONCLUSION: Results suggest that, generally, a positive influence from preceding movements was observed in the performance of the selected jumps. Jumps preceded by only one movement, show a tendency to an increase of the reached height. Due to an immature technique of performance, our ballet students, especially in the sequences of small jumps, did not use previous movements to potentiate the following jump tasks. More research should be done in this area and future studies should include more subjects for analysis and with a better technique of jump performance.

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