THORACOABDOMINAL MOTION DURING DIFFERENT EXERCISES OF CLASSICAL BALLET: PRELIMINARY RESULTS

Isabella Rodrigues[1,4], Gustavo Bernadina[1], Carlo Massaroni[2], Karine Sarro[3], Andres Chiapeta[4] Pietro Cerveri[5] and Amanda Silvatti[1]

Department of Physical Education, Universidade Federal de Viçosa, Viçosa, Brazil[1]
Unit of Mesurements and Biomedical Instrumentation, Università Campus Bio-Medico di Roma, Rome, Italy[2]
Faculty of Physical Education, Universidade Estadual de Campinas, São Paulo, Brazil[3]
Department of Physical Therapy, Faculdade de Ciências Biológicas e da Saúde, Viçosa, Brazil[4]
Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milan, Italy[5]

Once classical ballet requires high skill, physiological demand and intense exercises, the ballet dancers could develop different thoracoabdominal motions. In this work, we analyzed the thoracoabdominal motion of breathing maneuvers at rest situations and during different exercises of classical ballet. 32 retro reflective markers were attached to the trunk of three amateur ballet dancers to obtain the compartmental volumes variation (superior and inferior thorax and abdomen) and the coordination between them. They executed two breathing maneuvers (quiet breathing and vital capacity) and three ballet exercises (*adagio*, *allegro* and *fouette* turn). The results suggest that, in rest situations, ballet dancers can coordinate breathing movements, but during the exercises, they changed their thoracoabdominal motion causing a decrease in the coordination.

KEY WORDS: dance, breathing, kinematics.

INTRODUCTION: Classical ballet is a peak performance activity that has a sophisticated aesthetic and complex technique (Shah, 2008), demanding movements of great precision (Agostini, 2010). This field of dance requires a basic skill acquisition (dance class), performance preparation (rehearsal) and stage performance. The ballet class contains elements of warm-up (lower physical intensity) and center work (characterized by periods of intense activity lasting 10 to 40 seconds, with periods of rest of 2 to 5 minutes) (Wyon, 2005). The center work can be divided into three groups: *adagio*, *allegro* and turns. The *adagio* is a combination of slow and graceful movements that may be simple or complex, who develops a sustaining power, alignment, balance and dynamic force (Agostini, 2010). The *allegro* is characterized by a combination of fast and explosive jumps, who develops agility, dynamic balance, explosive strength (Agostini, 2010) and at the same time lightness. Among the different types of turns performed in a ballet class, the *fouette* is a classical ballet term meaning “whipped turns” and is characterized by continuous turns using a leg as axis. This exercise develops agility, dynamic and static balance and alignment (Agostini, 2010).
Despite the high skill, physiological demand and intensity of the exercises, dance must seem effortless since aesthetic is a key-point in ballet, and the control of breathing movements could be an important technique to the dancers. Consequently, this could develop different thoracoabdominal motions. As the dancer performs several types of exercises, the way that the dancer breathes during the exercises can affect the performance. The knowledge of dancer's thoracoabdominal movements during balletexercises is important to identify the breathing patterns that could support the development of a specific training to improve their breathing mechanics and performance. Therefore, the purpose of the present study was to present preliminary results of the thoracoabdominal motion characteristics during different exercises of classical ballet compared to breathing maneuvers performed in rest conditions.

METHODS: Three female amateur ballet dancers (age 20±5 years, height 1.64±0.04 m, weight 52.83±3.88 kg, at least 10 hours of classes and rehearsals per week and at least 10 years of classical ballet practice) participated of this study.
For three-dimensional kinematic analysis, eighteen OptiTrack cameras (Prime 17W, 360Hz) were positioned around the participants. For the analysis of thoracoabdominal movements, 32 retro-reflective markers were fixed on the trunk of participants (figure 1). This trunk representation model consists of four horizontal lines (2nd ribs, xiphoid process, 10th rib and transverse of the abdomen), and four vertical lines equally spaced (from the midline between the anterior axillary line and mid-axillary line), following a symmetrical four by four anterior and posterior grid. This model divides the trunk into three compartments: superior thorax (ST), inferior thorax (IT) and abdomen (AB) (Ferrigno et al., 1994). From the filtered 3D coordinates of the markers (Butterworth, cutoff 10Hz) we calculated the volumes of each trunk compartment as a function of time (Visual 3D).
In order to acquire the breathing maneuvers at rest, the participants stand up straight with their arms relaxed at the side of the body. They performed two trials of quite breathing (QB) and vital capacity (VC). Each QB trial was acquired lasting one minute. Each VC trial was composed by five cycles of maximum inspiration followed by maximum expiration. To analyze the breathing movements during the different ballet exercises, the dancers performed three exercises (figure 1): *adagio, allegro*, and *fouette* turn. A specific song for each exercise was used to all participants perform the exactly same movements in the same rhythm. Two trials of each exercise were acquired.

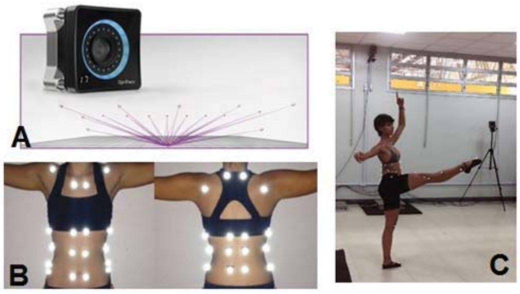

Figure 1: A) Cameras position; B) Markers protocol to calculate the trunk volume (Ferrigno et al., 1994); C) An example of the *adagio* performance by one of the participants.

The coefficient of variation was calculated to assess the relative percentage variation of the volumes of each compartment in each trial of the breathing maneuvers and exercises. The thoracoabdominal coordination was assessed by the calculation of the correlation coefficient between the trunk compartments (ST against IT, ST against AB and IT against AB) of each trial of the breathing maneuvers and exercises (Silvatti, Sarro, Cerveri, Baroni & Barros, 2012). Therefore, the correlation values equal to or near 1 indicate a high positive correlation, which means, in this case, that thoracoabdominal movements are coordinated and synchronized. Values equal or close to -1 indicate high negative correlation, which means, in this case, asynchrony in thoracoabdominal movement.
For each participant, we calculated the mean and the standard deviation of the coefficient of variation and the correlation coefficient of the two trials of each breathing maneuvers and exercises. Considering the small sample size, no statistical test was performed, the results were presented for each participant.

RESULTS: The coefficient of variation (table 1) showed that the participant 1 can maintain a greater activity of the AB in all the situations. The participant 2 had a greater activity of IT in QB, however in VC, *adagio*, *allegro* and *fouette* the compartment that showed a greater activity was the AB. The participant 3 showed a great activity of IT in QB and *adagio*, however in VC, *allegro* and *fouette* the compartment that presented a greater activity was the AB.
The thoracoabdominal movement coordination analysis (table 2) showed that the participant 1 had positive correlation coefficients in QB, VC, *allegro* and *fouette*, which characterizes

coordination of movements. During adagio, the participant showed asynchrony between STxIT, with negative value of correlation. The participant 2 showed positive correlation coefficients in QB, VC and *fouette* and during *adagio* the participant showed negative correlation values between STxIT, STxAB and between STxIT during *allegro*, meaning asynchrony. The participant 3 showed coordinate thoracoabdominal movements in all situations.

Table 1. Mean (SD) coefficient of variation (%) values of participant 1, 2 and 3 during QB, VC and the ballet exercises: *adagio, allegro* and *fouette*.

Participant		ST	IT	AB
	QB	1.25±0.16	1.69±0.53	1.69±0.17
	VC	3.18±0.08	3.08±0.09	3.84±0.71
1	*Adagio*	2.41±0.02	2.99±0.22	4.04±0.33
	Allegro	1.82±0.08	2.39±0.09	3.25±0.19
	Fouette	2.59±0.33	2.54±0.08	3.21±0.39
	QB	1.10±0.33	1.62±0.48	1.75±0.47
	VC	2.77±0.21	4.70±0.35	4.68±0.69
2	*Adagio*	2.68±0.18	5.85±0.27	3.69±0.34
	Allegro	2.08±0.35	5.87±0.02	4.76±0.00
	Fouette	2.09±0.11	4.17±2.23	3.21±0.79
	QB	1.96±0.16	3.14±0.35	3.09±0.52
	VC	2.86±0.05	4.39±0.32	7.29±0.31
3	*Adagio*	3.47±0.19	7.17±1.09	6.23±0.74
	Allegro	2.69±0.25	3.14±0.77	3.14±0.45
	Fouette	1.76±0.25	2.66±0.44	3.34±0.78

Table 2. Mean (SD) correlation coefficient values of participant 1, 2 and 3 during QB, VC and the ballet exercises: *adagio, allegro* and *fouette*.

Participant		STxIT	STxAB	ITxAB
	QB	0.92±0.04	0.90±0.03	0.84±0.12
	VC	0.96±0.01	0.94±0.01	0.94±0.01
1	*Adagio*	-0.06±0.13	0.08±0.02	0.69±0.06
	Allegro	0.41±0.04	0.28±0.09	0.74±0.03
	Fouette	0.20±0.34	0.24±0.19	0.77±0.01
	QB	0.94±0.00	0.51±0.08	0.53±0.08
	VC	0.98±0.01	0.90±0.03	0.91±0.03
2	Adagio	-0.12±0.09	-0.12±0.08	0.55±0.06
	Allegro	-0.08±0.12	0.15±0.20	0.67±0.01
	Fouette	0.12±0.05	0.51±0.11	0.60±0.03
	QB	0.96±0.01	0.93±0.01	0.94±0.00
	VC	0.94±0.00	0.79±0.01	0.86±0.01
3	Adagio	0.13±0.66	0.24±0.40	0.06±0.39
	Allegro	0.25±0.14	0.34±0.12	0.71±0.09
	Fouette	0.48±0.09	0.55±0.16	0.75±0.12

It is important to note that in all cases there was a decrease in thoracoabdominal movements coordination when the exercises were performed in comparison with QB and VC maneuvers.

DISCUSSION: The physical activity can optimize the breathing pattern (Barros et al., 2003; Sarro, Silvatti & Barros, 2008; Silvatti et al., 2012). An optimized breathing can be defined by an increasing: in the compartmental volume variation and in the coordination of movements between compartments. This mechanical optimization may allow an increasing in the inhalation and exhalation of the air, improving the breathing efficiency. An optimized

breathing pattern were found in swimmers (Silvatti et al, 2012) and yoga practitioners (Barros et al, 2003). Since we found high correlation values and a good volume variation, the ballet dancers showed an optimized breathing during QB and VC maneuvers.
According to Aliverti (2016), when high intensity exercises are performed the respiratory demands increased. However, in our work we found a decrease in the coordination when this kind of exercises were performed. This fact could affect the breathing efficiency.
The thoracoabdominal coordination had a high variation between all participants in the three exercises performed, which suggest that the breathing movements can vary according to the rhythm of the exercise. Duffin (1994) claim that the neural control of breathing can change proportionate to the change in the rhythm of the exercises. The decrease of the coordination during the exercise may also be related to the movement of the trunk and the contraction of abdomen for a greater trunk stability during the performance, which can limit the expansion of the thorax and abdomen to breathe. Each exercise has a different movement characteristic, which can lead to a variation in the thoracoabdominal movements coordination. The *adagio* showed a greater decrease in the thoracoabdominal coordination, which can be related to the elevation of the legs and greater amplitude of the trunk movements, who could cause a bigger thoracoabdominal limitation.
Despite the decreased in thoracoabdominal movements coordination, the participants could maintain a greater activity and coordination between IT and AB in almost situations evaluated. Although the results suggest that the participants can maintain a pattern of coordination between IT and AB during the exercises, they seem to adopt individual breathing strategies due to the greater variation in movement coordination and the volume variation of the compartments, which can be explained by the individual magnitude of respiratory response to exercise (Duffin, 1994).
Despite the small sample size, this study is important to a better understanding of the thoracoabdominal behavior of ballet dancers during exercise, that could provide some information to improve the breathing training applied to ballet practice. Techniques can be elaborated to teach how to coordinate the thoracoabdominal movements during breathing and how to it apply it in the ballet exercises.

CONCLUSION: The present study suggest that classical ballet dancers have an optimized breathing at rest situations, but when the exercises are performed there is a decrease in the thoracoabdominal coordination, which may affect the breathing efficiency and the performance. Further studies will be important for a better understanding of the respiratory mechanics of dancers during exercise for the elaboration of a respiratory training.

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