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ORIGINAL ARTICLE

Energy cost and energy sources of a ballet dance exercise in female adolescents with different technical ability

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Abstract This study evaluated energy cost and energy sources of a ballet exercise (*grand adage*) in young female dancers with different technical ability, and then related the energy sources to the subject's $\dot{V}O_{2\,max}$ and anaerobic threshold (IAT). Twenty-five dancers (13–16 years) were divided into two different technical ability groups: low-level ($n = 13$) and high-level ($n = 12$). The overall energy requirement of dance exercise (VO_{2eq}) was obtained by adding the amount of VO_2 during exercise above resting (aerobic source or VO_{2ex}) to the VO_2 up to the fast component of recovery (anaerobic alactic source or VO_{2al}) and to the energy equivalent of peak blood lactate accumulation (anaerobic lactic source or VO_{2la^-}) of recovery. VO_{2eq} of exercise amounted to 81 ± 10 and 94 ± 9 ml kg^{-1} in low-level and high-level groups, respectively. VO_{2ex} represented the higher fraction ($65 \pm 4\%$ and $77 \pm 5\%$) in low-level and high-level groups, respectively, of VO_{2eq} in both the groups. In the low-level group the remaining fractions were: 23 ± 2 % for VO_{2al} and $12 \pm 1\%$ for VO_{2la^-}. In high-level group the remaining fractions were: 18 ± 2 % for VO_{2al} and $4 \pm 1\%$ for VO_{2la^-}. Between two groups, significant differences were found in VO_{2ex} ($P < 0.01$), VO_{2la^-} ($P < 0.01$), and VO_{2al} ($P < 0.05$). IAT was 55 and 60% of $\dot{V}O_{2\,max}$ for low-level and high-level dancers, respectively. Low-level dancers performed more exercise above IAT than high-level. For these reasons, it should be better to define exercise intensity according to the IAT parameter and not only to $\dot{V}O_{2\,max}$.

Keywords Adolescent dancers · Oxygen uptake · Aerobic and anaerobic thresholds · Blood lactate

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Introduction

Dance is defined as a human movement that is formalized (e.g., by being stylized or performed in certain patterns) with qualities such as grace, elegance, and beauty, to the accompaniment of music or other rhythmic sounds, for the purpose of telling a story and/or for the purpose of communicating or expressing human emotions, themes, or ideas, and with the aid of mime, costumes, scenery, and lighting. By the first half of the eighteenth century, court ballets were superseded by "Classic Dance" using the five positions of the feet and the turnout of the legs that are still the foundation of classical ballet. In classical ballet, the performance is represented by the execution of a sequence of steps and figures to music that defines its rhythm and duration. Professional schools (such as Dance Academies, National Ballet Theater Schools, etc.,) have a limited enrollment, and admission is by audition only. Few pupils are admitted in professional schools, the majority attend recreational courses. There are a number of private classical ballet schools offering recreational courses rather than those for professional purposes. The aim of professional schools is to produce dancers who perform in international dance companies. The professional ballet school's curriculum is usually structured as an 8 year full-time training (11–18 years), in which grade five marks the beginning of the professional level. Private ballet students sometimes reach high esthetic and technical standards that allow them to be admitted through audition to study in a professional ballet school.

In spite of its long history and popularity, there is a paucity of information available on the physiological aspects of classical ballet (Koutedakis and Jamurtas 2004; Cohen et al. 1982; Schantz and Astrand 1984). Previous review and studies assessed various health factors in elite professional adult female ballet dancers including nutritional status, body composition characteristics, risk factors and injuries that occurred (Clarkson et al. 1985; Iwamoto and Takeda 2003; Khan et al. 1995). Clarkson et al. 1985 found that $\dot{V}O_{2\,max}$ of talented ballet dancers was 48.9 ml kg^{-1} min^{-1} while $\dot{V}O_{2\,max}$ of untrained girls of a similar age group (15 years) was ranging from 35.9 to 40.8 ml kg^{-1} min^{-1}. In general, professional adult dancers demonstrated lower maximal oxygen uptake values compared with endurance athletes (Koutedakis and Sharp 1999). $\dot{V}O_{2\,max}$ values of dancers related to their skill level, kind of dance they practised (Chmelar et al. 1988), and their parts in choreographed dance (Schantz and Astrand 1984, Wyon et al. 2007). Many studies (Kirkendall and Calabrese 1983; Cohen et al. 1982; Schantz and Astrand 1984) have reported the $\dot{V}O_{2\,max}$ for professional ballet (ranging 40–51 ml kg^{-1} min^{-1}), whereas few data of $\dot{V}O_{2\,max}$ for professional modern dance (49.1 ml kg^{-1} min^{-1}) have been reported (Chmelar et al. 1988). For university ballet and modern dancers the $\dot{V}O_{2\,max}$ values demonstrated a similar range from 41.5 to 50.7 ml kg^{-1} min^{-1} (Chmelar et al. 1988; Novak et al. 1978; Rimmer and Rosentswieg 1981–1982).

Recently, the physical demands placed on dancers from current choreography have made physiologic and fitness development equally important as skill development. Limited studies give us information about cardiorespiratory characteristics in young female ballet dancers (Baldari and Guidetti 2001; Clarkson et al. 1985); the effect of warm up on the energy sources of a ballet exercise (Guidetti et al. 2007a), and about metabolic responses to a typical ballet class (Guidetti et al. 2007b). During a ballet class, low technical level dancers were reported to often perform above their anaerobic threshold, indicating that they tend to utilize aerobic metabolism to a lesser extent than highly technical dancers. The typical ballet class is structured into two parts: *barre* exercises and center floor exercises. During the center floor phase, the exercise "*grand adage* on full *pointe*" is typically performed after an intense exercise such as *temps levés* or *sauté* (jumping at "allegro" tempo). In our previous study (Guidetti et al. 2007b) evaluating the ballet class, we found $\dot{V}O_{2\,max}$ values during *grand adage* that indicate a moderate intensity and high lactate levels indicating a high exercise intensity of the exercise (*temps levés*) performed before the *grand adage*. It could be expected that an exercise performed with slow movements (*adage*) would be of low-moderate intensity. The *grand adage* would be an effective active recovery from a high intensity exercise if its intensity was below the IAT (Baldari et al. 2004). Thus, it is of interest to know the exercise intensity and energy sources, of the *grand adage* exercise. Since to quantify the exercise intensity and sources it is necessary to avoid any influences of pervious high intensity exercises, in the present study we investigate the *grand adage* not as exercise of a whole lesson but as a single exercise.

Therefore, the purpose of the current study was to evaluate the exercise intensity of the *grand adage* in relation to the subject's $\dot{V}O_{2\,max}$ and anaerobic threshold, and to analyze the contribution from the different energy sources in young female dancers with different technical ability levels.

Methods

Subjects

Twenty-five female ballet dancers (13–16 years of age) participated as volunteers in this study. Signed parental consent was obtained from all the subjects, in accordance with the Institutional Review Board approved protocol. All subjects were: (1) healthy and in good nutritional status, (2) post-menarcheal girls, (3) not taking part in outside activity, and (4) attending a course in private dance schools where the technical program of classical ballet corresponded to grade five of the traditional teaching methods. The subjects were divided into two groups: 13 ballet dancers with low technical ability (group A), and 12 ballet dancers with high technical ability (group B). Dancers in group A had a technical proficiency as judged by their dance teachers, not sufficient to allow them to aim at participating in the selection for acceptance into a full-time professional school (at National level). Conversely, dancers in group B were judged by their dance teachers to have adequate technical proficiency to allow them to participate in the national selection. Due to their esthetic standard and proficient dance technique, each dancer passed the audition for acceptance into full-time professional program of the National Academy of Dance.

Practice regime differed between the two groups. Group A included dancers aiming for recreational purposes, and training an average of 4 h per week. Group B included dancers aiming for a professional career; therefore, spending more time in training—an average of 10–12 h per week over a period of at least 4 years. The number of subjects in each group was based on a sample size calculation performed on data from our previous publication (Baldari and Guidetti 2001; Guidetti et al. 2007b), yielding a statistical power >80%.

Experimental procedure

All dancers underwent a pre-testing session and one testing session not more than 48 h later, to avoid the effects of fatigue and muscle soreness on performance.

The pre-testing session consisted of anthropometric measurements and a continuous grade exercise test to determine IAT and $\dot{V}O_{2\,max}$. The testing session evaluated the energy cost of a ballet dance exercise.

Pre-testing session

Anthropometric measures

Weight and height were measured using a scale and a stadiometer to the nearest 0.02 kg and 0.1 cm, respectively. Skinfold thickness was measured to the nearest 0.2 mm using a caliper (Harpenden, St Albans, UK) on the right side of the body. All skinfolds were taken three times by the same person to ensure consistency in results with the average of the three values used as a final value. To predict body fat [FM (%)] the equation described by McArdle (McArdle et al. 1996) using five skinfolds (triceps, subscapular, suprailiac, abdominal, and thigh) was selected for this investigation.

Maximal oxygen uptake and IAT

To determine $\dot{V}O_{2\,max}$ and IAT, each dancer performed a maximal continuous treadmill test (Runrace HC 1200, Technogym, Forlì, Italy). $\dot{V}O_2$, ventilation $(\dot{V}E)$, and heart rate (HR) were recorded as average values every 30 s during the test by a telemetric portable device to determine gas exchange parameters (K4 b^2 COSMED, Rome, Italy). The transmitter unit and rechargeable battery were attached in the front and in the back of a chest harness, weighing less than 500 g (Meyer et al. 2005). The system was calibrated before and after each test using room air (21% O_2, 0.03% CO_2) and a certified gas mixture (16% O_2, 5% CO_2; Scott Medical Products, Plumsteadville, PA, USA). The turbine flowmeter was periodically calibrated using a 3 l syringe according to the manufacturer's instructions. The treadmill test consisted of a 3 min walk warm up at 6 km/h with a 0% of slope followed by an incremental protocol designed as follows: speed increased 1 km/h every 3 min up to 10 km/h running velocity, then slope increased every 3 min by 2%. $\dot{V}O_{2\,max}$ was identified at the occurrence of a plateau of $\dot{V}O_2$, despite further increase in workload or an increase in $\dot{V}O_2 < 1\ \text{ml kg}^{-1}\ \text{min}^{-1}$ in comparison with that produced by the previous workload (Metra et al. 1990). $\dot{V}O_2$ data were continuously measured breath by breath and later smoothed using a 6-breath moving average and reduced to 30 s averages. Secondary criteria were also applied to verify the maximal effort such as an attainment of age-predicted maximum heart rate and/or a respiratory exchange ratio >1.15 (Duncan et al. 1997).

To determine the individual anaerobic threshold (IAT), we used a simplified method which was previously validated (Baldari and Guidetti 2000). The IAT was determined by plotting an individual curve of $\dot{V}O_2$ versus La. In this curve, each lactate value was assigned to the work rate immediately prior to that of its measurement and consequently the individual $\dot{V}O_2$ versus La curve was plotted (Baldari and Guidetti 2000). The individual anaerobic threshold was defined as the work rate corresponding to the second lactate increase by at least 0.5 mmol l^{-1} from the previous value, where the second increase was greater (or equal) than the first one (Baldari and Guidetti 2000). The average of the last minute of the corresponding work rate was used to determine the oxygen consumption at IAT. Determination of blood lactate was carried out immediately after the collection of untreated capillary blood from a fingertip using an Accusport lactate analyzer (Boehringer Mannheim, Germany) (Bishop 2001). Blood lactate measurements were performed before exercise, at the third minute of each work rate without running interruption up to the work rate subsequent to IAT attainment (Baldari and Guidetti 2000), and at the third minute of the recovery phase.

Testing session

In the testing session, the energy cost of a ballet dance exercise was evaluated in both the groups. $\dot{V}O_2$ data were continuously measured breath-by-breath. Given the noise in the breath-by-breath display, editing of data was performed to exclude occasional errant breaths caused by swallowing, coughing, sighing, etc., which were considered not to be reflective of the underlying kinetics, i.e., only values greater than four standard deviations from the local mean were omitted (Özyener et al. 2001). The individual breath-by-breath $\dot{V}O_2$ responses were then smoothed using a 3-breath moving average and time-averaged to produce a standard weighted response at 10 s intervals, thereby reducing the "noise" and increasing the confidence of the parameter estimation. The oxygen consummation $(\dot{V}O_2)$was acquired breath-by-breath by a telemetric oxygen uptake measurements system (K4 b^2 COSMED) (Hausswirth et al. 1997) before, during and after the ballet exercise. After exercise, $\dot{V}O_2$ was acquired during 25 min of sitting recovery. Determination of blood lactate was carried out immediately after the collection of untreated capillary blood from a fingertip. The measurements were performed prior to ballet exercise and at rest. Lactate values were also determined at 1, 3, 5 and 7 min of recovery phase using an Accusport lactate analyzer (Boehringer Mannheim, Mannheim, Germany) (Bishop 2001).

Structure of *grand adage*

All subjects performed a *grand adage* as on *pointe* center exercise. As usual for dance practice, a warm up preceded the *grand adage* exercise. This warm up lasted 5 min and consisted of two *barre* exercises: pre-*barre* and *plié*. The *grand adage* exercise, lasting 210 s, was performed on *adagio* music (72 bpm, 4/4). The exercise was characterized by a sequence of movements performed twice in succession beginning with the left and then the right extremities. This ballet dance exercise consisted of a succession of slow, large amplitude, and graceful movements, from simple to most complex character, performed with fluidity and apparent ease. The principal steps of *grand adage* were *pliés, développés, dégagés, grand rond de jambe, rond de jambe en l'air, coupés, battements tendus, attitudes, arabesques, preparations for pirouettes,* and *pirouettes*. These steps develop a sustaining power, sense of line, balance, and the beautiful poise which enables the dancer to perform with majesty and grace.

Data analysis

The overall energy requirement of dance exercise (VO_{2eq}) was obtained by adding up contributions of the three energy sources (di Prampero 1981; Beneke et al. 2002) as previously described in detail (Guidetti et al. 2007a):

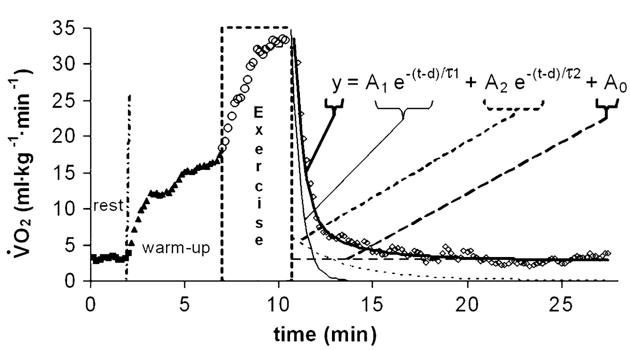

Fig. 1 Individual values of oxygen uptake $(\dot{V}O_2)$ curves before, during (210 s exercise), and after *grand adage*. Post-exercise $\dot{V}O_2$ was analyzed using a double-exponential equation described in the text and shown in this figure (best fitting recovery curve as *continuous bold line*). The first exponential term describe the fast component (*continuous line*), the second exponential term the slow component of $\dot{V}O_2$ (*dotted line*), and the third term the baseline value (*dashed line*)

1. The aerobic source was calculated from the VO_2 above rest during *grand adage* exercise.
2. The anaerobic alactic source (VO_{2al}) was estimated from the fast component of the post-*grand adage* exercise VO_2 (Fig. 1) (di Prampero et al. 1970; Beneke et al. 2002). To determinate the kinetics of the fast and slow component of the $\dot{V}O_2$ recovery curve, a modified double-exponential model (Özyener et al. 2001) was applied:

$$\dot{V}O_2(t) = A_1 \times e^{-(t-d)\tau 1} + A_2 \times e^{-(t-d)\tau 2} + A_0$$

where $\dot{V}O_2(t)$ is the oxygen uptake at time t, A_1 and A_2 are the amplitudes of the fast and slow components, respectively, τ_1 and τ_2 (seconds) the corresponding time constant and A_0 is the $\dot{V}O_2$ at rest (ml/min), d is the time delay common to the fast and slow components. The model was applied using a non-linear least squares fitting procedure (Origin, Microcal, Northampton, USA).

3. The anaerobic lactic source (VO_{2la^-}) was determinate from net blood lactate accumulation (Δ_{la^-}), during recovery time. The net increase of lactate in blood was obtained by subtracting the rest value from the peak value attained at the recovery phase. The energy equivalent of 1 mmol l^{-1} blood lactate increase was assumed to be 3 ml O_2 kg^{-1} (di Prampero 1981). Thus, net energy produced from anaerobic lactic acid metabolism was $3 \times \Delta_{la^-}$.

Statistical analysis

Mean and standard deviations (SD) were calculated for all the variables. For all variables, the unpaired t test ascertained differences between the two groups of dancers with different technical ability level (low and high). P values less then 0.05 were considered as statistically significant.

Results

The anthropometric characteristics of group A were: age 14.2 ± 1.4 years, height 1.63 ± 0.05 m, mass 50.2 ± 3.1 kg, BMI 19.3 ± 1.7, FM 23.2 ± 3.6%. The characteristics of group B were: age 13.7 ± 1.0 years, height 1.61 ± 0.04 m, mass 45.2 ± 6.8 kg, BMI 17.6 ± 1.8, FM 20.7 ± 3.4%. Body mass and BMI were significantly higher in group A than group B ($P < 0.05$). The oxygen consumption at maximal effort $(\dot{V}O_{2\,max})$ was significantly lower ($P < 0.05$) in group A than group B (38.1 ± 1.9 and 46.2 ± 2.1 ml kg^{-1} min^{-1}, respectively). The individual anaerobic threshold (IAT) was significantly lower in group A than group B, both when expressed as absolute values

Table 1 Overall energy cost of a *grand adage* ballet exercise (VO_{2eq}) in ml kg^{-1} (mean ± SD), its partition (mean ± SD) among aerobic (VO_{2ex}), alactic (VO_{2al}), and lactate (VO_{2la^-}) sources and as percentage values of VO_{2eq} in low (group A) and high technical ability dancers (group B)

	Group A		Group B	
	ml kg^{-1}	VO_{2eq} (%)	ml kg^{-1}	VO_{2eq} (%)
VO_{2ex}	53 ± 6	65 ± 4	73 ± 8**	77 ± 5**
VO_{2al}	19 ± 2	23 ± 2	17 ± 2*	18 ± 2*
VO_{2la^-}	10 ± 1	12 ± 1	4 ± 1**	4 ± 1**
VO_{2eq}	81 ± 10		94 ± 9**	

* $P < 0.05$ versus group A, $^{**}P < 0.01$ versus group A

(20.9 ± 0.9 and 27.7 ± 2.5 ml kg^{-1} min^{-1}, respectively, $P < 0.01$) and as relative values (55 ± 5% and 60 ± 5% of $\dot{V}O_{2\,max}$, respectively, $P < 0.05$).

The overall energy requirement (VO_{2eq}) of *grand adage* exercise, performed by each subject, is the sum of the contribution of the three energy sources described below.

1. *Aerobic source*. The amount of O_2 consumed above resting during *grand adage* (VO_{2ex}) was significantly higher in group B (Table 1).
2. *Anaerobic alactic source*. The $\dot{V}O_2$ curve during recovery was described by a double-exponential model ($r^2 = 0.98$; Fig. 1). For $\dot{V}O_2$ fast component, values of A_1 were 30.8 ± 7.0 ml kg^{-1} min^{-1} and 33.6 ± 8.7 ml kg^{-1} min^{-1}in A and B group, respectively, delay d were 0.01 ± 0.003 s and 0.01 ± 0.004 s in A and B group, respectively, and values of time constant τ_1 were 39 ± 10.9 s and 31 ± 5.8 s, in A and B group, respectively. VO_{2al} estimated from the fast component was significantly lower in group B as shown in Table 1.
3. *Lactate source*. Lactate peak occurred 3 min after exercise, values were 4.5 ± 0.4 and 2.5 ± 0.3 mmol l^{-1} in A and B group, respectively, $P < 0.01$. The lactate values prior to ballet exercise were 1.3 ± 0.2 and 1.2 ± 0.1 mmol l^{-1} in A and B group, respectively. The net increase of peak lactate value (Δ_{la^-}) was of 3.2 ± 0.3 and 1.3 ± 0.2 mmol l^{-1} in A and B group, respectively. The energy equivalent of lactate accumulation in blood expressed in VO_{2la^-} ($VO_{2la^-} = 3 \cdot \Delta_{la^-}$) was significantly lower in group B as shown in Table 1.

The overall energy cost (VO_{2eq}) of exercise differed between two groups as shown in Table 1. The dancers' technical level significantly affected the partition of the different sources during exercise (Table 1). The overall energy requirement (i.e. metabolic power requirement) for *grand adage* exercise was 60% of subject's $\dot{V}O_{2\,max}$ in both the groups.

Discussion

Our results showed that, despite the term *grand adage* might suggest, the intensity of this exercise was very demanding for all dancers, taxing both aerobic and anaerobic processes. In fact, ballet exercise involves a strong static component in conjunction with a dynamic component. These components are particularly important for balance, muscular control, maintaining body placement, positioning of the arms and upper body, and supporting the body weight on one leg while the other leg moves.

$\dot{V}O_{2\,max}$ of high technical ability dancers was higher than low technical ability dancers. Moreover, consistent with the mixed aerobic–anaerobic nature of ballet (Schantz and Astrand 1984), both high and low technical level dancers in the present study had maximal oxygen uptake values below the average for other athletes (Koutedakis and Sharp 1999). Ballet involves a strong static component in conjunction with a dynamic component consisting of bursts of high intensity, for brief duration. Ballet training consists of technique and style training with an aim to increase the skill level of dancers.

Nevertheless, our study showed a different maximal oxygen uptake values between the groups (higher in group B than group A). The better aerobic fitness of high technical level dancers would not be related to their class work, but to the duration and frequency of their performances as previously reported by Kirkendall and Calabrese (1983). In fact, dancers in group A were training an average of 4 h per week, while dancers in group B were training on the average 10–12 h per week over a period of at least 4 years. Dance consists of human movements involving qualities such as grace and style. However, current choreography places physical demands on dancers that make their physiologic and fitness development just as important as skill development (Redding and Wyon 2003).

Overall energy cost obtained by adding up contributions of the three energy sources was similar to that obtained with the method traditionally used for submaximal exercise lasting for more than 2 min (i.e., evaluating the $\dot{V}O_2$ average of the last 30 s and referred to the whole exercise). The overall energy requirement (VO_{2eq} in ml, i.e., expressed not in relation to body weight) of the *grand adage* was not influenced by technical level of dancers. Comparing the energy cost of ballet exercise between the dancers with different technical level, high-level dancer has a better economy of movement. However, on the other hand, the low-level dancer usually executes ballet figures with a lower width of movements; therefore, resulting in a lower energy requirement. In our study, these two aspects were well balanced so that the overall energy cost of the *grand adage* exercise was similar between high and low technical level dancers.

The overall energy cost (VO_{2eq} in ml kg^{-1}, i.e., expressed in relation to body weight) was significantly lower in group A than group B, indicating a lower energy requirements per kg body mass. This difference was due to the significantly lower body mass in talented dancers (group B). Low body mass and BMI in talented dancers are in agreement with the esthetic standard of classical ballet requiring a "sylph-like" body type (Clarkson et al. 1989).

The contribution of three energy sources was significantly different between the two groups. The aerobic system was the most taxed in both groups (65 and 77% in group A and B, respectively). However, the contribution of the aerobic source

was significantly higher in high technical ability dancers (group B) than in low technical ability dancers (group A). Anaerobic lactic system contribution was higher in group A than group B (12 and 4% in group A and B, respectively). These differences could depend on the different fitness levels of dancers. In fact, dancers belonging to group A had a lower fitness level than dancers of group B as indicated by $\dot{V}O_{2\,max}$ and IAT values. This could depend not only on time spent in practicing dance (lower in group A than group B), but also on technical expertise they reached in classical dance (high level in group B) according to a previous study that showed a strong correlation between technical expertise and fitness parameters in young female ballet dancers (Guidetti et al. 2007b).

Dance fitness depends on the individual's ability to work under aerobic (Clarkson et al. 1985; Cohen et al. 1982) and anaerobic conditions (Koutedakis and Jamurtas 2004), and on their capacity to develop high levels of muscle tension, i.e., muscle strength (Clarkson et al. 1985). Individual anaerobic threshold was 55 and 60% of $\dot{V}O_{2\,max}$ for dancers belonging to group A and B, respectively. In accordance with these results, Seip et al. (1991) reported that trained athletes have an individual anaerobic threshold at a higher percentage of their $\dot{V}O_{2\,max}$ than untrained athletes.

The overall energy requirement (i.e., metabolic power requirement) for *grand adage* exercise was 60% of subject's $\dot{V}O_{2\,max}$ in both groups. This percentage is above IAT for dancers of group A but not for dancers of group B. Consequently, anaerobic sources are more taxed by dancers in group A. These variations are relevant since IAT represents the highest workload that can be maintained over a long duration without constantly increasing the lactate levels (McLellan and Cheung 1992). Exercise intensity is usually defined as percentage of maximal oxygen uptake or maximal heart rate (Schantz and Astrand 1984; Cohen et al. 1982). However, the IAT represents a validated physiological breakpoint in the determination of exercise intensities.

Our results are in accordance with Meyer et al. (2005). In fact, we demonstrated that exercise prescription at preset percentages of $\dot{V}O_{2\,max}$ corresponds to wide ranges of exercise intensities as defined in relation to the IAT. Thus, the exercise intensities in the athletes' training should not be planned on percentage of $\dot{V}O_{2\,max}$ or HR_{max} alone, without considering the IAT.

Some authors (Schantz and Astrand 1984; Cohen et al. 1982) found that oxygen uptake averaged about 43–46% of $\dot{V}O_{2\,max}$ during the center floor phase of normal classes while oxygen uptake was about 80% of $\dot{V}O_{2\,max}$ during *solo parts* of choreographed dance. As these authors suggested, the oxygen uptake of center floor exercises could be underestimated due to the brief duration of each exercise (15–85 s), which would not allow measuring $\dot{V}O_2$ in steady-state conditions. The choreographed parts lasted between 1 and 12 min and were performed on different music tempo inducing different speeds of execution (from slow to fast) (Schantz and Astrand 1984). In our investigation, the overall energy requirement of *grand adage* was 60% of $\dot{V}O_{2\,max}$. The duration of *grand adage* exercise (210 s) was longer than most of center floor exercises (Schantz and Astrand 1984; Cohen et al. 1982) but not different to some choreographed exercises (Schantz and Astrand 1984). The high oxygen uptake reported for choreographed parts (80% of $\dot{V}O_{2\,max}$) may be due to the speed of movements, which were executed also with the fast music, whereas, the relative slow movements of *grand adage* (performed with a music tempo 72 bpm, 4/4) induced a lower energy requirement (60% of $\dot{V}O_{2\,max}$).

The *grand adage* is usually performed during a typical ballet class, as center floor exercise on full *pointe* and consequently it could be preceded and followed by other dance exercises. This exercise is made up of slow and large amplitude movements; therefore, it could be supposed that it would be low-moderate intensity. When the *grand adage* follows a high intensity exercise, it could be the optimal intensity for an effective active recovery if it is performed below the IAT (Baldari et al. 2004). Our study suggested that this hypothesis could be true only for high technical ability dancers and not for low technical ability dancers.

In the present work, we studied energy cost and energy sources of a ballet dance exercise in young talented female dancers with two different technical ability levels. In conclusion, we showed that overall energy requirement (VO_{2eq}) of *grand adage* was not different between two groups. The aerobic contribution remained the major energy source in both dancers groups. However, talented dancers performed the *adage* exercise around their IAT, whereas, the low technical level dancers performed above their IAT. In fact, the anaerobic lactic system was more taxed in low compared to high technical level dancers. Even though the overall energy requirement for *grand adage* exercise was 60% of $\dot{V}O_{2\,max}$ in both the groups, the high technical level dancers utilized the aerobic source more than the low technical level dancers, due to their higher IAT. The ballet teaching methods are essentials for maintaining and developing the dancers' technique and coordination to perform an artistic form of movement. Since classical ballet body movement expression is closely linked with a high physical performance (Schantz and Astrand 1984), ballet classes need supplemental cardiovascular training to improve the fitness level, (Krasnow and Chatfield 1996; Wyon MA 2004; Guidetti et al. 2007b) especially in low technical level dancers.

Even if the most taxed metabolism of *grand adage* ballet exercise was the aerobic source, its percentage of utilization was related to the fitness level of the performer. A higher percentage allows a better performance, since the anaerobic lactic metabolism is less utilized. Moreover, ballet teachers should be aware that *grand adage* exercise would represent an effective active recovery when performed after an intense ballet exercise (such as technical jumps) only for high technical level dancers and not for low technical level dancers.

This confirms that exercise intensity should not be defined only as a percentage of $\dot{V}O_{2\,max}$, but it is preferable to define the individualized intensity in relation to the IAT.

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