The Characteristics of Physical Fitness Related to Athletic Performance of Male and Female Sport Dancers

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Abstract
The aim of this research was to define specific characteristics of physical fitness of dancers and couples of dancers when analyzing them in relation to their dancing efficiency indices. Quantitative and qualitative characteristics of functional power, fast kinetics and economy indicated high requirements for the high functionality of dancers-athletes. This can be seen from the indicators of the reaction power of the cardiorespiratory system and the energy supply of work. Differences of indicators: relative oxygen uptake (VO₂ max); pulmonary ventilation (V̇E); carbon dioxide production (VCO₂), anaerobic threshold (AT) for both partners were statistically significant (p<0.05). At the same time, high requirements have been set for the fast kinetics and economy of the reaction. It is shown that the quantitative characteristics of the fast kinetics: half-time reaction of oxygen uptake (T_{50} VO), pulmonary ventilation (T_{50} V̇E); carbon dioxide production (T_{50} VCO₂), heart rate (T_{50} HR) and cost-effectiveness characteristics: oxygen heart rate at maximal oxygen uptake (V̇O₂/HR at VO₂ max), oxygen heart rate at anaerobic threshold (V̇O₂/HR at AT); ventilatory equivalent for carbon dioxide at anaerobic threshold (VE/VCO₂ at AT); ventilatory equivalent for oxygen at anaerobic threshold (VE/VO2 at AT); ventilatory equivalent for oxygen at maximal oxygen uptake (V̇E/VO2 at VO₂ max); oxygen uptake percentage at anaerobic threshold from maximal oxygen uptake (%VO₂AT from VO₂ max -1 ) between partners do not differ significantly. This made it possible to analyze the integral functional readiness of the pair and compare the characteristics of sportsmen-dancers of high and low qualifications.

Keywords: dancesport, aerobic power, efficiency, fast kinetics responses

Introduction
It is a well-known fact that sport training in every sport has specific requirements towards athlete’s body, determined by the contents of the tournament program. In dancesport, duration of a dancing program is 7 to 8 minutes with 2 to 3 minutes rest interval between different dance types. At the prestigious dancing tournaments athletes complete the dancing program from three to seven times. In every round of a competition, the duration of Waltz, Tango, Foxtrot, Quickstep, Samba, Cha-cha-cha, and Paso Doble must be not less than minute and a half for each, and not less than a minute for Viennese Waltz and Jive. Dance tempo is from 28-30 bars per minute to 58-60 bars per minute in Standard program and from 25-27 bars per minute to 60-62 bars per minute in Latin program. All the above factors combined define high specific physical fitness requirements for dancers.

In recent years, high levels of power supply response indices during dance sport have been recorded and in individual
cases reached $60.9 \pm 6.0 \text{ ml/kg}^{-1}\text{·min}^{-1}$ (VO$_{2\text{max}}$) and $9.0 \pm 2.1 \text{ mmol}^{-1}\text{(La)}$ (Bria et al., 2011; Beck, Wyon, & Redding, 2018).

Based on the provided data a notion about high strain of functions, and consequently, about possibly increasing role of fatigue buildup for specific performance of dancers was formed. Level and pattern of fatigue buildup are defined by high specific physical fitness. Its differences increase differences of partners’ specific performance during competition. This may be evidenced by such indices of physical fitness as VO$_{2\text{max}}$ and capability of its realization along with an increasing fatigue during dance, change in pulmonary ventilation response and HR at anaerobic threshold and more. As a result of differences in key physical fitness characteristics, range of individual differences related to fatigue buildup may increase. For instance, a mismatch was observed between lactate-acidose levels reached during a Standard program dance ($8.5 \pm 2.3^{-1}$ for men, $8.3 \pm 3.9 \text{ mmol}^{-1}\text{·min}^{-1}$ for women) and aerobic power (VO$_{2\text{max}}$), providing for the compensation of increasing acidemic shifts ($45.8 \pm 6.0 \text{ ml/kg}^{-1}\text{·min}^{-1}$ for men, $38.0 \pm 8.5 \text{ ml/kg}^{-1}\text{·min}^{-1}$ for women) (Faina, Bria, Scarpellini, Gianfelici, & Felici, 2001). Fatigue was observed to have most significant influence in semifinal during the performance of the 4th and 5th dances of competition program. In the final, the fatigue appears and influences on the dancers’ skills demonstration during the 2nd and 3rd dances (Dalla Vedova, Besi, Cacciari, Bria, & Faina, 2006; Rodrigues-Krause, Krause, & Reischak-Oliveira, 2015).

However, existing data, in most cases, relate to physical fitness measurements and analysis of functional abilities Meta Max 3B (Cortex, Germany). The research included 24 dancers comprising of 12 couples: men of $22.8 \pm 5.0$ and women of $21.3 \pm 4.2$ years of age. The athletes formed a homogeneous national and international level in terms of their qualification. They all belonged to Ukraine’s national dance sport team and were winners of prestigious international category A Tournaments. All of them had official tournament experience of $5.2-9.5$ years. Training load within a week amounted to $12.5 \pm 1.1$ hours.

**Research organization**

The research took place during a period of preparation preceding a competition following the voluntary written consent of athletes and approval by the local commission on bioethics of scientific research. All experiment participants took no medication, doping, or other stimulating substances.

**Methods**

**Subjects**

The research included 24 dancers comprising of 12 couples: men of $22.8 \pm 5.0$ and women of $21.3 \pm 4.2$ years of age. The athletes formed a homogeneous national and international level in terms of their qualification. They all belonged to Ukraine’s national dance sport team and were winners of prestigious international category A Tournaments. All of them had official tournament experience of $5.2-9.5$ years. Training load within a week amounted to $12.5 \pm 1.1$ hours.

**Test exercises**

We used two test exercises. The first exercise (standard test) consisted of a steady activity – running with standard load at $3.0 \text{ m·s}^{-1}$ for 6 minutes with a $0^\circ$ incline of a treadmill. The second exercise consisted of a gradually increasing load on a treadmill according to VO$_{2\text{max}}$ measuring protocol (MacDougall, Wenger, & Green, 1991). The whole exercise included 4-5 subsequent stages (intensity levels). Each stage lasted 2 minutes. Load level was increased by changing incline angle (in degrees) of a treadmill by $0.5^\circ$ with a constant speed of $3.0 \text{ m·s}^{-1}$.

**Measurements and equipment**

Analysis of physical fitness characteristics was performed based on the assessment of power, kinetics and response efficiency indices in two tests.

**First test**

Fast kinetics of response (T50) were defined for VO$_{2}$, VCO$_{2}$, $V_{E}$ and HR in a 6 min standard load test (in the process of transition from the state of rest while standing on a treadmill) using monoexponential dependence according to S. Ward (Whipp & Ward, 1992). The second test was performed after 1 minute rest.

**Second test**

We measured VO$_{2}$ levels, CO$_{2}$ emission, pulmonary ventilation and heart-rate. VO$_{2\text{max}}$ and anaerobic threshold (AT) were defined. These indices were registered during gradually increasing load. They were oriented towards a characteristic of ability for the quick development of function (fast kinetics indices), effective functional maintenance of work (functional efficiency indices) and for the evaluation of those response indices of CRS that characterize functional capacity limits of the athletes (power indices). Evaluation was performed based on maximum VO$_{2}$ levels, CO$_{2}$, pulmonary ventilation and HR, as well as indexes of relation between the said responses at AT and VO$_{2\text{max}}$ ($V_{E}/VO_{2}$ at AT, $V_{E}/VO_{2}$ at VO$_{2\text{max}}$, $V_{E}/VCO_{2}$ at AT, $V_{E}/VCO_{2}$ at VO$_{2\text{max}}$; VO$_{2}$/HR at VO$_{2\text{max}}$, %VO$_{2}$AT from VO$_{2\text{max}}$).

We used a system for ergonomic and physiological assessment of athletes’ functional abilities Meta Max 3B (Cortex, Germany).

**Statistical analysis**

The statistical analysis used the Statistical Package for Statistical analysis used the Statistical Package for
the Social Sciences (SPSS 26.0). The following methods of the mathematical statistics are descriptive statistics, selective method, criterion of consent of Shapiro Wilk, non-parametric criteria of Mann-Whitney. To determine the statistical significance of the differences between samples were used parametric criteria (t-test) for those samples, which corresponded to the normal distribution, and non-parametric criteria for small samples (Wilcoxon test) in other cases. A significance level (that is, the probability of error) was assumed to be \( p \leq 0.05 \). The informativeness of the tests and indicators was recorded, evaluated under the standard conditions of measurement.

Results

During a gradually increasing load, we assessed the different aspects of physical fitness of male and female dancers comprising in the abovementioned 12 couples. Body mass and height of the men were 70.7±5.8 kg and 179.8±5.1 cm, respectively; of women — 51.5±4.3 kg and 164.9±3.8 cm. We evaluated power, fast kinetics and response efficiency indices.

It should be noted that there were significant individual differences in body length and weight both among men and women. Thus, we took athletes’ body mass into account when choosing most of the indices for evaluating functional abilities (Table 1). Statistically significant differences of reaction power indices (\( VO_{2\text{max}}, V_{\text{E}max}, V_{\text{CO}_2} \)) for male and female partners needed to apply special evaluation criteria for these reaction indices for male and female partners apart (Bria et al., 2011).

Analysis of indices representing maximum oxygen consumption level, \( CO_2 \) emission, anaerobic threshold (AT) and HR revealed that maximum CRS response indices were high.

The value of indices at the AT level were high in men and had a significant range of individual differences. Thus, no statistically significant differences in \( CO_2 \) emission and HR indices were recorded.

CRS response indices at the AT level relative to maximum indices in women were at the level of 81.9 % for \( VO_2 \), 67.6 % for \( V_{\text{E}} \), 76.7 % for \( V_{\text{CO}_2} \) and 94.4 % for HR at AT, the same indices in men were as follows: 72.4 % for \( VO_2 \), 58.8 % for \( V_{\text{E}} \), 64.8 % for \( V_{\text{CO}_2} \), and 88.9 % for HR. For \( VO_2 \) and HR max differences were significant.

Further, we considered indices characterizing fast kinetics of aerobic energy supply responses and respiratory compensation of metabolic acidosis during high-intensity movement. For this, we considered initial kinetic indices and relative indices between response level, \( O2 \) consumption and \( CO2 \) emission levels. The latter are defined as characteristics of CRS response efficiency.

An analysis of fast kinetics of oxygen consumption, carbon dioxide emission, pulmonary ventilation and heart rate was made during a 6-minute test with a standard physical load. The analysis demonstrated that differences between male and female dancers were statistically insignificant (Table 2). A high level of individual differences in all indices was registered, as evaluated by CV.

There were no significant differences recorded in the indices of ventilation equivalent for \( O2 \) and \( CO2 \) consumption

### Table 1. Maximum indices of oxygen uptake, \( CO_2 \) emission, and thresholds of pulmonary ventilation response and HR at the maximum load intensity, and at the level of load intensity corresponding to dancers’ anaerobic threshold

| Indices                      | Men (n=12) | Women (n=12) | Differences of indices between men and women |
|------------------------------|------------|--------------|---------------------------------------------|
|                              | \( \bar{X} \) | SD  | CV | \( \bar{X} \) | SD  | CV | \( t \) | \( p \) |
| \( VO_{2\text{max}}, \text{ml·kg}^{-1}·\text{min}^{-1} \) | 54.8 | 3.1  | 5.7 | 47.5 | 3.5  | 7.4 | t=5.85 | 0.000007 |
| \( V_{\text{E}}, \text{ml·kg}^{-1}·\text{min}^{-1} \) | 1614.9 | 186.9 | 11.6 | 1247.5 | 132.9 | 10.7 | t=8.18 | 0.000001 |
| \( V_{\text{CO}_2\text{max}}, \text{ml·kg}^{-1}·\text{min}^{-1} \) | 57.9 | 2.7  | 4.7 | 50.3 | 2.5  | 5.0 | t=8.02 | 0.000001 |
| \( V_{\text{E}max}, \text{ml·kg}^{-1}·\text{min}^{-1} \) | 39.7 | 7.9  | 19.9 | 38.9 | 7.6  | 19.5 | t=0.23 | 0.820795 |
| \( V_{\text{CO}_2\text{at AT}, \text{ml·kg}^{-1}·\text{min}^{-1}} \) | 950.0 | 221.0 | 23.3 | 842.8 | 96.9 | 11.5 | t=5.12 | 0.000004 |
| \( V_{\text{E}at AT, \text{ml·kg}^{-1}·\text{min}^{-1}} \) | 37.5 | 5.5  | 14.7 | 38.6 | 6.4  | 16.6 | t=3.73 | 0.00152 |
| \( HR\text{max}, \text{beat·min}^{-1} \) | 185.8 | 5.3  | 2.9 | 173.5 | 5.4  | 3.1 | t=2.81 | 0.010105 |
| \( HR\text{at AT, \text{beat·min}^{-1}} \) | 165.2 | 7.4  | 4.5 | 163.8 | 5.9  | 165.2 | t=0.35 | 0.728307 |

Legend: \( VO_{2\text{max}} \) - relative oxygen uptake; \( V_{\text{E}max} \) - minute ventilation; \( V_{\text{CO}_2\text{max}} \) - maximum of carbon dioxide production; \( V_{\text{E}at AT} \) - oxygen uptake at anaerobic threshold; \( V_{\text{E}at AT} \) - minute ventilation at anaerobic threshold; \( V_{\text{CO}_2\text{at AT}} \) - carbon dioxide production at anaerobic threshold; \( HR\text{max} \) - maximal heart rate; \( HR\text{at AT} \) - heart rate at anaerobic threshold.

### Table 2. Indices of fast kinetics of oxygen uptake, carbon dioxide emission, pulmonary ventilation and heart rate of dancers

| Indices                      | Men (n=12) | Women (n=12) | Differences of indices between men and women |
|------------------------------|------------|--------------|---------------------------------------------|
|                              | \( \bar{X} \) | SD  | CV | \( \bar{X} \) | SD  | CV | \( t \) | \( p \) |
| \( T_{50\text{VO}_2}\text{s} \) | 28.3 | 5.6  | 19.8 | 29.3 | 4.3  | 14.7 | t=0.45 | 0.629760 |
| \( T_{50\text{V}_\text{E}}\text{s} \) | 26.9 | 6.3  | 23.4 | 27.6 | 4.0  | 14.5 | t=0.31 | 0.759366 |
| \( T_{50\text{CO}_2}\text{s} \) | 26.5 | 5.6  | 21.1 | 28.0 | 4.3  | 15.4 | t=0.73 | 0.47592 |
| \( T_{50\text{HR}}\text{s} \) | 28.0 | 5.0  | 17.6 | 28.3 | 4.9  | 17.3 | t=1.32 | 0.199847 |

Legend: \( T_{50\text{VO}_2}\) - half-time reaction of oxygen uptake; \( T_{50\text{V}_\text{E}}\) - half-time reaction of pulmonary ventilation; \( T_{50\text{CO}_2}\) - half-time reaction of carbon dioxide production; \( T_{50\text{HR}}\) - half-time reaction of heart rate.
ration at AT load level to VO₂ max, O₂ consumption and HR of men and women (Table 3). Those indices mostly characterized efficiency of dancers’ work when going through a gradually increasing test.

Differences in ventilation equivalent indices for O₂ and CO₂ at VO₂ max were statistically significant (р<0.05). The fact worth noticing is a high level of individual differences in ventilation equivalent for O₂ and CO₂, for both men and women, in the period of reaching maximum rate of work at the AT intensity level. This may be indicative of differences in the intensity of respiratory compensation of metabolic acidosis when reaching maximum response values, as well as at AT intensity level.

Analysis of the rapid kinetics and economy of couples with high and low skill levels showed a high level of requirements for the indicated reaction components, as well as significant differences (р<0.05) of the indicated reaction characteristics in athletes of high and low qualifications.

A number of physical fitness characteristics of dancers in couples with high and lower level of specific mastery is represented in Table 4. We compared a group of athletes that had high average score for performing 5 dances (Group 1) with a group having lower athletic mastery indices (Group 2). Groups of athletes (pairs of dancers) with higher athletic mastery levels had higher values of VO₂ max and VE max indices, as well as fast kinetics and response efficiency indices, corresponding physical fitness of athletes.

### Table 3. Characteristic relation between VO₂ and HR, O₂ uptake at anaerobic threshold load level, as well as pulmonary ventilation with VO₂ and CO₂ in men and women

| Indices                                      | Men (n=12) | Women (n=12) | Differences of indices between men and women |
|----------------------------------------------|------------|--------------|---------------------------------------------|
| VO₂/HR at VO₂ max, ml·min⁻¹·beat⁻¹          | 19.4       | 17.2         | t=6.16 р=0.000003                            |
| VO₂/HR at AT, ml·min⁻¹·beat⁻¹                | 16.2       | 14.3         | t=5.02 р=0.000049                            |
| VE/VO₂ at VO₂ max                           | 25.3       | 21.8         | t=1.02 р=0.549424                            |
| VE/VO₂ at AT                                | 23.9       | 21.7         | t=1.74 р=0.095084                            |
| %VO₂AT from VO₂ max                         | 70.6       | 78.4         | t=1.11 р=0.377802                            |

Legend: VO₂/HR at VO₂ max- oxygen heart rate at maximal oxygen uptake; VO₂/HR at AT- oxygen heart rate at anaerobic threshold; VE/VO₂ at VO₂ max- ventilatory equivalent for oxygen at maximal oxygen uptake; %VO₂AT from VO₂ max- oxygen uptake percentage at anaerobic threshold from maximal oxygen uptake.

### Table 4. Basic physical fitness characteristics of pairs of dancers (n=24, 12 couples) having different athletic mastery levels

| Indices                                      | Couples with higher athletic mastery (first group, n=12) | Couples with lower athletic mastery (second group, n=12) | Differences of indices |
|----------------------------------------------|-------------------------------------------------------|-----------------------------------------------------|------------------------|
| T₅₀ VO₂, s                                   | 24.1 ± 2.1                                           | 31.1 ± 2.1                                          | t=6.02 р=0.000005      |
| T₅₀ Vₑ, s                                    | 23.0 ± 1.9                                           | 32.4 ± 3.9                                          | t=7.21 р=0.000001      |
| T₅₀ CO₂, s                                   | 26.1 ± 2.1                                           | 27.2 ± 2.2                                          | t=7.86 р=0.000001      |
| T₅₀ HR, s                                    | 21.1 ± 2.9                                           | 28.8 ± 2.3                                          | t=6.37 р=0.000002      |
| VO₂/HR at VO₂ max, ml·min⁻¹·beat⁻¹           | 18.5 ± 1.1                                           | 15.9 ± 1.0                                          | t=2.59 р=0.016533      |
| VO₂/HR at AT, ml·min⁻¹·beat⁻¹                | 15.8 ± 1.1                                           | 12.9 ± 1.0                                          | t=3.15 р=0.004615      |
| %VO₂AT from VO₂ max                          | 80.6 ± 5.0                                           | 66.1 ± 5.0                                          | t=1.04 р=0.278801      |
| Vₑ/VO₂ at VO₂ max                            | 25.2 ± 1.0                                           | 21.1 ± 1.7                                          | t=4.51 р=0.000173      |
| Vₑ/VO₂ at AT                                 | 27.7 ± 2.1                                           | 21.6 ± 1.9                                          | t=3.97026 р=0.000644   |
| Vₑ/VO₂ at VO₂ max                            | 26.9 ± 2.1                                           | 20.0 ± 2.0                                          | t=6.13 р=0.000004      |
| Vₑ/VO₂ at AT                                 | 27.7 ± 2.0                                           | 21.9 ± 1.5                                          | t=5.49 р=0.000016      |

Legend: T₅₀ VO₂- half-time of oxygen uptake; T₅₀ Vₑ- half-time of minute ventilation; T₅₀ CO₂- half-time of carbon dioxide production; T₅₀ HR- half-time of heart rate; VO₂/HR at VO₂ max- oxygen heart rate at maximal oxygen uptake; VO₂/HR at AT- oxygen heart rate at anaerobic threshold; %VO₂AT from VO₂ max- oxygen uptake percentage at anaerobic threshold from maximal oxygen uptake; Vₑ/VO₂ at VO₂ max- ventilatory equivalent for oxygen at maximal oxygen uptake; Vₑ/VO₂ at AT- ventilatory equivalent for oxygen at anaerobic threshold; Vₑ/VO₂ at VO₂ max- ventilatory equivalent for carbon dioxide at maximal oxygen uptake; Vₑ/VO₂ at AT- ventilatory equivalent for carbon dioxide at anaerobic threshold.
Discussion

High body tension at dance sport events is commensurate with the body tension of the sports integrating the elements of both sports and art: figure skating, gymnastics, sport aerobics (Boudolos, 2005; Lankford et al., 2014; Marra et al., 2019). Parties with the sports above are convergent by nature and thus do not allow to define the significance of functional fitness nor outline the factors to substantially boost specific endurance in dancers and efficacy of competitive performance as a whole. This is because the content of competitive performance in dancing is unique and unprecedented among other sports. It’s common knowledge that the differences of competitive performance structure predetermine the differences of special endurance and, consequently, the ones of training process direction (MacDougall et al., 1991; Mishchenko & Monogarov, 1995; Korobeynikov et al., 2020). Therefore, means to apply methods of special endurance improvement from hard-coordinating kinds of sports to dance sport are limited.

At the basis of this research there lies an approach that has proven efficacy in sports practice including the kinds of sport combining sporting and art elements. A specific sequence of actions was used to study the core functional fitness in dancers with a couple. This can have a significant impact on components (power, fast kinetics and efficiency of responses) considerable individual differences between them. This is the significant differences of indexes in males and females despite the assessed. The comparative analysis results did not show significant differences of fast kinetics and efficiency of responses were low anaerobic limit in vast majority of athletes pointed out the necessity to assess other functional characteristics of athletes (Boudolos, 2005; Lankford et al., 2014; Marra et al., 2019). Par- 
ties both sports and art: figure skating, gymnastics, sport aerobics with the body tension of the sports integrating the elements of the integral functional readiness of the pair and compare the characteristics of sportsmen-dancers of high and low qualifications. Analysis of the rapid kinetics indicators and cost-effectiveness characteristics of these response characteristics underlie the dancer’s working capacity. This is evidenced by a higher level of rapid kinetics indicators and economy of reactions among highly qualified dancers. The importance of assessing these characteristics is that the normative levels of the men’s and ladies’ reactions do not differ significantly. High integral manifestations of the indicated physical fitness components form the conditions of a stable state of both partner’s functions during a long period of competitive activity. At the same time, there was formed an understanding that such differences can serve as a reason for a high tension of the functional provision of the special working capacity of one of the partners, the development of early fatigue and, as a consequence, a decrease in the demonstration of dance skills demonstration. There is an evidence to assume that the adjustment of a dancer’s functional fitness to functional competitive performance significantly increases the quality of a dancer’s training.

Conclusion

The data represented in the research indicates new opportunities of assessment and improvement of directed functional fitness with regard to specific functionality and endurance in a dance couple. The received data shows that a constant increase of competitive performance tension in dancesport corresponds to an increase in the values of factors of fatigue suppression and specific decrease in the process of dancing program performance.

Therefore, a significant performance improvement in dancesport stimulates the improvement of those aspects of functional abilities that are most influential to athletic excellence. This can be seen in the indicators of fast kinetics and the economy of the reaction. It is shown that the quantitative characteristics of the fast kinetics (Tₚ/VO₂, Vₚ/VO₂, Vₚ/VCO₂, HR) and cost-effectiveness characteristics (VO₂/HR, Vₚ/VCO₂, Vₚ/VO₂ at VO₂ max) between partners do not differ significantly. This made it possible to analyze the integral functional readiness of the pair and compare the characteristics of sportsmen-dancers of high and low qualifications. Analysis of the rapid kinetics and economy of couples with high and low skill levels showed a high level of requirements for the indicated reaction components, as well as significant differences (p <0.05) of the indicated reaction characteristics in athletes of high and low qualifications.

In view of the aforesaid, a functional training program can be created specifically for this kind of sport based on the differences in the functional fitness of the couple – a current trend for further studies of dance training.

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Conflict of Interest

The authors declare that there are no conflicts of interest.

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