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

Chenguang Mu[1], Igor Soronovych[1], Andrii Diachenko[1], Olesia Khomiachenko[1], Svitlana Popova[1], Di Huang[1], Ivan Cherniavskyi[1], Olha Kaluzhna[1] and Oksana Boyko[1]

[1]National University of Physical Education and Sports of Ukraine, Department of Dance Kinds of Sports and Choreography, Kyiv, Ukraine

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 (VO_2max); pulmonary ventilation (V_E); carbon dioxide production (VCO_2), 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} VE); carbon dioxide production ($T_{50}VCO_2$), heart rate (T50 HR) and cost-effectiveness characteristics: oxygen heart rate at maximal oxygen uptake (VO_2/HR at VO_2 max), oxygen heart rate at anaerobic threshold (VO_2/HR at AT); ventilatory equivalent for carbon dioxide at anaerobic threshold (VE/VCO_2 at AT); ventilatory equivalent for carbon dioxide at maximal oxygen uptake (V_E/VCO_2 at VO_2max); ventilatory equivalent for oxygen at anaerobic threshold (VE/VO2 at AT); ventilatory equivalent for oxygen at maximal oxygen uptake (V_E/VO_2 at VO_2 max); oxygen uptake percentage at anaerobic threshold from maximal oxygen uptake (%VO_2AT from VO_2max^{-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

Correspondence:

I. Soronovych
National University of Physical Education and Sport of Ukraine, Department of Choreography and Dance Kinds of Sport, Vulytsya Fizkultury 1, office 5-407, Kyiv-03150, Ukraine
E-mail: soronovych@ukr.net

cases reached 60.9±6,0 ml·kg^{-1}·min^{-1} (VO_2 max) and 9.0±2.1 mmol·l^{-1}(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_2max 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±2.3^{-1} – men, 8.3±3.9 mmol·l^{-1} – women) and aerobic power (VO2 max), providing for the compensation of increasing acidemic shifts (45.8±6.0ml·kg^{-1}·min^{-1} –men, 38.0±8.5 ml·kg^{-1}·min^{-1} – 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, relates to stating the existence of high requirements towards energy supply of work performed and don't give a comprehensive description of specifics of such requirements towards functional capabilities of dancers. It is clear that it is hardly possible to limit their adequate assessment to defining maximum oxygen consumption and anaerobic threshold (Vissers et al., 2011; Beck, Redding, & Wyon, 2015). As stated, there is a necessity to single out other characteristics of functional capabilities specific for dancers. We were especially interested in analyzing differences between functional preparedness of male and female dancers. It is well known that these differences do influence the level of special efficiency and demonstration of dancers' skills (Lankford et al., 2014).

We preceded from the fact that physical fitness and dancers' ability to withstand fatigue are based on the increase in aerobic energy supply efficiency in the general energy balance of work considering its specific mode in dance sport. Interpretation of CRS response may be based on the evaluation of ability to quickly, adequately and fully respond to physical load typical for dancers during competitions (Lankford et al., 2014; Burzynska, Finc, Taylor, Knecht, & Kramer, 2017). Based on the above, criteria for specialized enhancement of physical fitness in both partners separately and a couple in general may be improved. Dedicated literature currently contains no such data. It could be based on studying the quantitative and qualitative characteristics of functional ability which deliver the high function deployment speed and long period of stable condition of functions. For that we will need to study the characteristics of fast kinetics and economy of dancers-athletes.

The aim of this study was to define high specific characteristics of dance physical fitness of individual dancers and couples when analyzing against dance performance indices taking into account possible differences of functional preparedness between partners. This can become a prerequisite for making physical and functional training more purpose oriented.

Methods

Subjects

The research included 24 dancers comprising of 12 couples: men of 22.8±5.0 and women of 21.3±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±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.

Test exercises

We used two test exercises. The first exercise (standard test) consisted of a steady activity – running with standard load at 3.0 m·s^{-1} for 6 minutes with a 0° incline of a treadmill. The second exercise consisted of a gradually increasing load on a treadmill according to VO_2 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° with a constant speed of 3.0 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 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 max (V_E/VO_2 at AT, V_E/VO_2 at VO_2 max, V_E/VCO_2 at AT, V_E/VCO_2 at VO_2max, VO_2/HR at VO_2max, %VO_2AT from VO_2 max).

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

Statistical analysis

The 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_2max, V_E, VCO_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).

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_2max, ml·kg^{-1}·min^{-1}	54.8	3.1	5.7	47.5	3.5	7.4	t=5,85	p=0.000007
V_E, ml·kg^{-1}·min^{-1}	1614.9	186.9	11.6	1247.5	132.9	10.7	t=8.18	p=0.000001
VCO_2max, ml·kg^{-1}·min^{-1}	57.9	2.7	4.7	50.3	2.5	5.0	t=8.02	p=0.000001
VO_2at AT, ml·kg^{-1}·min^{-1}	39.7	7.9	19.9	38.9	7.6	19.5	t=0.23	p=0.820795
$V_E$at AT, ml·kg^{-1}·min^{-1}	950.0	221.0	23.3	842.8	96.9	11.5	t=5.12	p=0.00004
VCO_2at AT, ml·kg^{-1}·min^{-1}	37.5	5.5	14.7	38.6	6.4	16.6	t=3.73	p=0.00152
HR max, beat·min^{-1}	185.8	5.3	2.9	173.5	5.4	3.1	t=2.81	p=0.010105
HR at AT, beat·min^{-1}	165.2	7.4	4.5	163.8	5.9	165.2	t=0.35	p=0.728307

Legend: VO_2 max - relative oxygen uptake; V_E- minute ventilation; VCO_2max - maximum of carbon dioxide production; VO_2at AT - oxygen uptake at anaerobic threshold; V_E at AT- minute ventilation at anaerobic threshold; VCO_2at AT- carbon dioxide production at anaerobic threshold; HR max-maximal heart rate; HR at AT- heart rate at anaerobic threshold.

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_E, 76.7 % for VCO_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_E, 64.8% for VCO_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 O_2 and CO_2, O_2 consumption

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} VO_2, s	28.3	5.6	19.8	29.3	4.3	14.7	t=0.45	p=0.629760
T_{50} V_E, s	26.9	6.3	23.4	27.6	4.0	14.5	t=0.31	p=0.759366
T_{50} CO_2, s	26.5	5.6	21.1	28.0	4.3	15.4	t=0.73	p=0.47.592
T_{50} HR, s	28.0	5.0	17.6	28.3	4.9	17.3	t=1.32	p=0.199847

Legend: T_{50} VO_2- half-time reaction of oxygen uptake; T_{50} V_E - half-time reaction of pulmonary ventilation; T_{50} CO_2 - half-time reaction of carbon dioxide production; T_{50} HR - half-time reaction of heart rate.

ration at AT load level to VO_2 max, O_2 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 O_2 and CO_2 at VO_2 max were statistically significant ($p<0.05$). The fact worth noticing is a high level of individual differences in ventilation equivalent for O_2 and CO_2, 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 ($p<0.05$) 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 VO_2 max and VE max indices, as well as fast kinetics and response efficiency indices, corresponding physical fitness of athletes.

Table 3. Characteristic of relation between VO_2 and HR, O_2 uptake at anaerobic threshold load level, as well as pulmonary ventilation with VO_2 and VO_2 in men and women

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/HR at VO2 max, $ml\cdot min^{-1}\cdot beat^{-1}$	19.4	2.0	10.3	17.2	2.1	12.2	t=6.16	p=0.000003
VO_2/HR at AT, $ml\cdot min^{-1}\cdot beat^{-1}$	16.2	2.1	13.0	14.3	2.1	14.7	t=5.02	p=0.000049
VE/VCO_2 at AT	27.9	3.2	11. 5	24.7	2.8	11.3	t=0.61	p=0.549424
VE/VCO_2 at VO_2 max	25.3	3.3	13.0	21.8	3.8	17.4	t=1.02	p=0.549424
V_E/VO_2 at AT	23.9	2.7	11.3	21. 7	2.7	12.5	t=1.74	p=0.095084
V_E/VO_2 at VO_2 max	29.5	3.90	13.23	26.26	4.20	16.0	t=0.53	p=0.18952
$\%VO_2AT$ from VO_2max^{-1}	70.6	10.0	14.2	78.40	12.2	15.6	t=1.1	p=0.377802

Legend: VO_2/HR at VO_2 max- oxygen heart rate at maximal oxygen uptake; VO_2/HR at AT, $ml\cdot min^{-1}.beat^{-1}$- oxygen heart rate at anaerobic threshold; V_E/VCO_2 at AT - ventilatory equivalent for carbon dioxide at anaerobic threshold; V_E/VCO_2 at $VO2_2$ max- ventilatory equivalent for carbon dioxide at maximal oxygen uptake; V_E/VO_2 at AT- ventilatory equivalent for oxygen at anaerobic threshold; V_E/VO_2 at VO_2 max- ventilatory equivalent for oxygen at maximal oxygen uptake; $\%VO_2AT$ from VO_2max^{-1}- 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	
	$\bar{x}$	*SD*	*CV*	$\bar{x}$	*SD*	*CV*	t	p
T_{50} VO_2, s	24.1	2.1	8.71	31.1	2	6.43	t=6.02	p=0.00005
T_{50} V_E, s	23.0	1.9	8.26	32.4	3	9.26	t=7.21	p=0.000001
T_{50} CO_2, s	26.1	2.1	8.05	27.2	2.2	8.09	t=7.86	p=0.000001
T_{50} HR , s	21.1	2	9.48	28.8	2.3	7.99	t=6.37	p=0.000002
VO_2/HR at VO_2 max, $ml\cdot min^{-1}$ $beat^{-1}$	18,5	1,1	5,9	15,9	1,0	6,3	t=2.59	p==0.016533
VO_2 /HR at AT, $ml\cdot min^{-1}\cdot beat^{-1}$	15,8	1,1	7,0	12,9	1,0	7,8	t=3.15	p=0.004615
$\%VO_2AT$ from VO_2max	80.6	5,0	6.20	66.1	5,0	7.56	t=1.04	p=0.278801
V_E/VO_2at VO_2max	25.2	1,0	3.97	21.1	1.7	8.06	t=4.51	p=000173
V_E/VO_2at AT	27.7	2.1	7.58	21.6	1.9	8.80	t=3.97026	p=0.000644
V_E/VCO_2 at VO_2max	26.9	2.1	7.81	20.0	2.0	10.00	t=6.13	p0.000004
V_E/VCO_2at AT	27.7	2.0	7.22	21.9	1.5	6.85	t=5.49	p=0.000016

Legend: T_{50} VO_2- half-time of oxygen uptake; T_{50} V_E - half-time of minute ventilation; T_{50} CO_2 - half-time of carbon dioxide production; T50 HR - half-time of heart rate; VO_2/HR at VO_2 max- oxygen heart rate at maximal oxygen uptake; VO_2/HR at AT, $ml\cdot min^{-1}.beat^{-1}$- oxygen heart rate at anaerobic threshold; $\%VO_2AT$ from VO_2max^{-1}- oxygen uptake percentage at anaerobic threshold from maximal oxygen uptake; V_E/VO_2 at VO_2 max- ventilatory equivalent for oxygen at maximal oxygen uptake; V_E/VO_2 at AT- ventilatory equivalent for oxygen at anaerobic threshold; V_E/VCO_2 at VO_2 max- ventilatory equivalent for carbon dioxide at maximal oxygen uptake; V_E/VCO_2 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). Parities 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, making it compliant with the sport`s requirements as the foundation for further content of training. Such an approach predetermines the development of highly specialized training means and programs along with general and specific functional training (Vissers et al., 2011; Watson et al., 2017; Yin et al., 2019). This approach does not only stipulate the comprehensive evaluation of physical fitness, but differentiation of its major components as well. Determination of the physical fitness components relation with major efficacy indexes of competitive program performance is one of the accepted means of such determination. One of the key tasks of implementing such an approach in research is to select a set of physical fitness indexes and comprehensive group of indexes reflecting specific physiologic properties of the performance energy supply. Three groups of indexes were outlined in this research, reflecting such physiologic CRS properties as power, fast kinetics and efficiency (Mishchenko & Monogarov, 1995).

Reaction limits indexes in dancers are indicative of high potential capabilities of the performance energy supply system (aerobic power) in the majority of the assessed athletes. At the same time, CRS response indexes were low at high tension levels of anaerobic limit in a vast number of dancers. The relatively low anaerobic limit in vast majority of athletes pointed out the necessity to assess other functional characteristics of athletes that boost the efficacy of aerobic energy supply. To this end, the indexes of fast kinetics and efficiency of responses were assessed. The comparative analysis results did not show significant differences of indexes in males and females despite the considerable individual differences between them. This is the indicative of considerable differences on the level of various components (power, fast kinetics and efficiency of responses) in dancers with a couple. This can have a significant impact on athletic skills. Therefore, the secondary endpoint is to define key characteristics of athletic skills and compare them with the components.

The analysis showed the importance of assessing the indicators of the cardiorespiratory system reaction and the work's energy supply of the athletes-dancers. The assessment of fast kinetics indicators and cost-effectiveness characteristics of work is of particular interest. The research has shown that 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 stipulates 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 ($T_{50}VO_2$, V_E, VCO_2, HR) and cost-effectiveness characteristics (VO_2/HR, V_E/VCO_2, V_E/VO_2 at VO_2 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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