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Original Investigation

The Ballroom Aerobic Test for estimating cardiorespiratory fitness in standard style dancesport athletes: diagnostic accuracy against laboratory measures

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Purpose: The main purpose of the study was to investigate the sensitivity properties of a newly developed Ballroom Aerobic Test (BAT) protocol for cardiorespiratory fitness against objective methods.
Methods: Twenty-four young dancesport couple athletes who competed at international level were recruited (age 20.40±3.90 years; stature 172.10±8.70 cm; body mass 60.10±9.40 kg; 50.00% women). Physiological parameters from the field-based BAT protocol were evaluated using the MetaMax® 3B portable gas analyzer, while objective data were generated on the running ergometer following the KF1 and Bruce protocols. The area under the curve (AUC), sensitivity, specificity, false positive (FP), false negative (FN), positive likelihood ratio (PLR) and negative likelihood ratio (NLR) were calculated.
Results: The AUC for the BAT against the KF1 and Bruce protocols yielded satisfactory values of > .75, with the largest agreements for absolute (AUC = .92; 95% CI .82 – 1.00 and .94; 95% CI .90 – 1.00) and relative maximal oxygen uptake ($\dot{V}O2max$; AUC = .94; 95% CI .90 – 1.00 and .95; 95% CI .86 – 1.00). Other ventilatory and metabolic parameters yielded somewhat lower AUC values (.65 ≤ AUC ≤ .93). Sensitivity and specificity analyses exhibited acceptable agreement percentages between the BAT and KF1/Bruce protocols, ranging from 66.70% to 95.10% for sensitivity and 60.00% to 100.00% for specificity. The largest PLRs were shown for relative $\dot{V}O2max$ in both KF1 (10.31) and Bruce (11.05) protocols.
Conclusions: This study shows that the BAT protocol may be considered as a good diagnostic tool for evaluating ventilatory and metabolic parameters of standard style dancesport athletes.

Keywords: Diagnostic testing; Dance; Physiological parameters; Sensitivity; Specificity.

Introduction

Dance is often seen as a vigorous form of exercise that demands higher levels of muscular and cardiorespiratory capacities.[1] Being able to handle the rigors of training and competition in dance is essential, underscoring the importance of physiological capabilities.[2] Research indicates that having a strong aerobic capacity is vital for success in dance. It's crucial for dancers to be efficient in how they take in, transport, and use oxygen to enhance their performance.[3] Interestingly, studies show that both semi-professional and professional dancers typically have lower maximal oxygen uptake ($\dot{V}O_{2max}$) compared to athletes from other sports. In fact, dancers in competitive dance sports exhibit a $\dot{V}O_{2max}$ that is about 30% lower than that of athletes involved in mono-structural and team sports.[4] One possible reason for this lower $\dot{V}O_{2max}$ in dancers may be linked to the limited ability of dance training to induce significant training adaptations. Findings suggest that improvements in aerobic capacity are more related to the intensity and duration of physical performance rather than rehearsal activities. This approach is key to effectively boosting their aerobic performance. From a practical view, complex dance movements do not necessarily mean intensity, but rather complexity. The shortcoming of dance is a lack of standardized or sport-specific protocols integrated into routine training and defined dance structures through which both intensity and duration are achieved. Thus, aerobic endurance is maintained or even increased through multiple repetitions of dance routines and choreography.[5]

In the realm of dance, it is essential to evaluate aerobic capacity using objective tools like heart rate monitors and ergometers to customize training programs for each individual.[6] Assessing an athlete's cardiovascular and respiratory abilities is vital for effectively regulating the training load and aiming for beneficial aerobic results during the preparatory phase. Nonetheless, measuring 'maximal' aerobic levels in dance is challenging due to its non-competitive aspects and the predetermined intensity set by the choreographer. Conventional objective techniques for measuring aerobic performance, such as running- or cycling-based ergometers, are not ideal for dance because they are expensive, complicated to implement, and fail to mimic the complex movements required in dance.[7,8] In a complex, aesthetic, and skill-based discipline (like dance or parkour), where traditional testing is inadequate, reinforcing the need for ecologically valid tests is warranted.[8,9] To address these limitations, previous studies have endeavored to develop on-field aerobic tests specifically tailored for dance. A systematic review by Tiemens et al.[4] identified several common cardiorespiratory fitness test protocols in dance, including the Aerobic Power Index (API),[10] the Ballet-specific Aerobic Fitness Test (B-DAFT),[11] the Dance Aerobic Fitness Test (DAFT),[12] the High-Intensity Dance Performance Fitness Test (HIDT),[13] and the Seifert Assessment of Functional Capacity for Dancers (SAFD).[14]

Despite attempts to accurately forecast aerobic results based on objective methods from dance-specific testing protocols,[10-14] the majority of earlier studies have linked $\dot{V}O_{2max}$ and maximal heart rate (HR_{max}) using a single device.[13,14] Ultimately, the tests that are available have mostly been created for ballet or contemporary dancers[12-15] on a personal basis, whereas the diagnostic aspects in ballroom dance pairs participating in standard dance styles have not been explored. Ballet and contemporary dancers follow distinct training regimens and movement styles in contrast to traditional dance performers.[16] From a biomechanical point of view, ballroom dancers tend to have higher knee extension torque movements, accompanied by greater hip external and internal rotations, and hip extension, opposed to more traditional dance disciplines,[16,17] Also, studies have shown that ballroom dancers, being more competitive and sport-related, in comparison to ballet and contemporary dancers, have more hamstring muscle length and dynamic balance, indicating higher levels of physical fitness.[17] Lower mobility in the pelvis region found in ballet dancers might indicate more intra-articular lesions, followed by discomfort and pain more frequently.[17] The biomechanical problem in the lumbo-sacral region may also indicate a complex association with altered gait biomechanics, specifically kinematics and kinetics of the dance movements. Greater dynamic balance in ballroom dancesport athletes leads to a lower risk of sport-related lower limb injury rate. Moreover, ballet dancers exhibit an even lower percentage of accumulated fat mass, often falling below 10%, whereas ballroom dancers typically keep their fat mass percentage between 10 and 20%, respectively.[17] From a physiological point of view, typical male and female ballroom dancers generally exhibit higher average $\dot{V}O_{2max}$ values[16] when compared to ballet or contemporary dancers.[10-14] This suggests that elevated $\dot{V}O_{2max}$ and peak heart rate (HR_{peak}) are usually required to sustain high-level performance and meet the challenges of training and competition demands.[17] From a discipline-specific perspective, ballroom dancesport competitors originating from modern dance usually enhance their aerobic capacity and peak performance at varying rates, whereas those from other endurance sports generally see a gradual increase in their aerobic abilities throughout their careers.[17] Conversely, when examining the maximal aerobic capacity of dancers relative to other endurance sport athletes, the mean $\dot{V}O_{2max}$ is recorded at 48.0 ml·kg^{-1}·min^{-1}, whereas it varies from 55.0 to 77.0 ml·kg^{-1}·min^{-1} among swimmers, middle- and long-distance runners, rowers, and triathletes.[1] Notably, the $\dot{V}O_{2max}$ in dancers aligns with sedentary activities (≈ 44.0 ml·kg^{-1}·min^{-1}), emphasizing that the endurance of dancesport athletes is cultivated solely during dance performances, while endurance training designed for improvement remains unexplored.[1] Consequently, aerobic capacities and field tests in these dancers cannot be applied to other dance forms, as a result of varied physiological profiles and training/competition routines throughout the preparatory and competitive phases.[1,4] Through the analysis of consistent training and performance with a designated test to evaluate aerobic capacity, coaches and choreographers can oversee and record the cardiovascular and respiratory requirements of various standard dance styles and can modify training volume to address physiological improvements. Therefore, the main purpose of the study was to examine the sensitivity properties of a newly developed Ballroom Aerobic Test (BAT) protocol for cardiorespiratory fitness against objective methods. We hypothesized that the BAT protocol would yield satisfactory sensitivity and specificity values in comparison to laboratory-based aerobic capacity tests.

Materials and methods

Experimental approach

This observational sub-study, conducted within subjects, aimed to assess the diagnostic characteristics of the BAT in standard dancesport athletes. The research was a component of a project titled 'Development and validation of a testing protocol to evaluate aerobic capacity in dancesport competitors from standard dance styles.' The project was split into four segments to investigate: i) reliability and utility; ii) validity; iii) diagnostic accuracy; and iv) practical validity of the BAT. Portions of the text have been published recently regarding the validity properties of the BAT protocol, where we used continuous data to evaluate correlations and Bland-Altman analyses between the BAT against the KF1/Bruce protocols. Of note, the standard error of estimate (SEE) for relative $\dot{V}O_{2max}$ was 3.36 ml·kg^{-1}·min^{-1} (KF1) and 3.75 ml·kg^{-1}·min^{-1} (Bruce).[18] In this study, two standard progressive treadmill tests (the KF1 and Bruce protocols) were evaluated to measure aerobic capacity, with the BAT protocol conducted one week later. The testing process commenced during the training phase of dancesport competitors. Assessments were carried out by the same skilled researcher to prevent potential measurement inaccuracies. During the tests, the participants donned their usual dance gear (light T-shirt, tights, dance shoes). The indoor facility and laboratory's air temperature was maintained between 22°C and 24°C, with a humidity level of approximately 55%

Study participants

Twenty-four standard dancesport athletes (12 dance couples; age 20.4±3.9 years; stature 172.1±8.7 cm; body mass 60.1±9.4 kg) with 8.2±3.4 years of training and competing experience participated in the study. All participants were members of certified dance clubs who competed at national and internation level. The inclusion criteria to enter the study were: i) being free from any kind of injury, acute or chronic illness and disease confirmed by a certified dance association doctor; ii) age range between 16 and 35 years; and iii) complete both measurements for validity properties of the BAT protocol. The *a-priori* power analysis calculated by the G*Power software ver. 3.1.9.7[19] showed that by setting the input parameters of a two-tailed $P<.05$, a minimum required correlation between the two methods at $R>.69$, and statistical power of 1-β= .95, the required total sample size was n=16. Because of a possible drop-out rate, we enlarged the sample size by 50% to n=24. Before the study began, all participants had signed a written informed consent to participate in the study and to use data solely for scientific purposes. All procedures in the study were anonymous and in accordance with the Declaration of Helsinki.[20]

The BAT protocol

To assess the level of aerobic capacity of dance sport athletes, we constructed a field-based BAT protocol. The protocol was standardized by 5 standard dance styles with the following order: i) English waltz; ii) Slow fox; iii) Tango; iv) Viennese waltz; and v) Quick step. Every dance style had multiple level of dancing that were progressively linked, where the speed of dancing (tempo) was defined by individual beats per minute (b·pm^{-1}), and by beat (bars per minute – BPM) denoting rhythm. The English waltz consisted of 6 levels, danced in 3/4 time in the range of 25–37 BPM or 75–110 BPM. The Slow fox included 5 levels, danced in 4/4 time in the range of 29–36 BPM or 117–145 BPM. The Tango had 5 levels, danced in 4/4 time in the range of 38–45 BPM or 152–180 bpm. The Viennese waltz was carried out through 3 levels, danced in 3/4 time in the range of 62-67 BPM or 187–201 BPM. Finally, the Quick step consisted of 6 levels, danced in 4/4 time in the range of 52-60 BPM or 208–243 BPM At each level, dance couples had to perform standard dance figures for 30 sec at a defined speed without the melody (Table 1). The speed expressed in beats progressively increased throughout the protocol by 7 BPM. The initial speed of the dance protocol was set at 75 BPM. Participants danced on a pre-defined dance tempo and rhythm by following the metronome. The elements for each dance style were basic and easy to perform, with the freedom of dance couples to create their own choreography. The duration of the BAT protocol was cumulatively added up and each pair danced until exhaustion.

The MetaMax® 3B outcomes

To examine the reliability properties of the BAT protocol, we used the MetaMax® 3B (CORTEX Biophysik GmbH, Leipzig, Germany), a reliable and valid portable breath-by-breath ventilatory and metabolic measurement system specifically designed for field- and laboratory-based testing.[21] The device was composed of two parts designed to be worn on the chest. By using an electrochemical cell and an infrared analyzer, the MetaMax® 3B was able to calculate O_2 and CO_2 concentrations based on standard metabolic equations.[22] Based on manufacturer's recommendations and previous studies,[21] the system was turned on for at least 20 min and calibrated prior to the testing. The calibration process included adjusting the gas analyzers by using reference gas values of O_2 (14.97%), CO_2 (4.96%) and N_2 (± 0.02%) and volume with a standardized 3-L syringe (5530 series, Hans Rudolph, Inc., MO, USA). The MetaMax® 3B software generated data regarding absolute (l·min^{-1}) and relative $\dot{V}O_{2max}$ (ml·kg^{-1}·min^{-1}) and associated variables including respiratory exchange ratio of CO_2 produced to O_2 consumed during metabolism (RER), expiratory ventilation as the total volume of air inhaled or exhaled per min (VE; l·min^{-1}), tidal volume as the volume inhaled or exhaled during a normal breath (VT; L), ventilatory equivalent for O_2 (VE/VO_2) and CO_2 (VE/VCO_2) as determinants of breathing efficiency, and dead space to tidal volume ratio (VD/VT), which indicated the air that failed to participate in O_2 and CO_2 exchange process during breathing.

Table 1. The BAT dance protocol for every dance style.

Dance styles	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
English waltz						
Beats (bpm^{-1})	75	82	89	96	103	110
Time (min)	0.5	1.0	1.5	2.0	2.5	3.0
Slow fox						
Beats (bpm^{-1})	117	124	131	138	145	
Time (min)	3.5	4.0	4.5	5.0	5.5	
Tango						
Beats (bpm^{-1})	152	159	166	173	180	
Time (min)	6.0	6.5	7.0	7.5	8.0	
Viennese waltz						
Beats (bpm^{-1})	187	194	201			
Time (min)	8.5	9.0	9.5			
Quick step						
Beats (bpm^{-1})	208	215	222	229	236	243
Time (min)	10.0	10.5	11.0	11.5	12.0	12.5

Note: Ballroom Aerobic Test (BAT).

The KF1 and Bruce testing protocols

$\dot{V}O_{2max}$ and metabolic parameters were assessed by a breath-by-breath pulmonary gas exchange system (Quark b^2, COSMED, Italy) during an incremental treadmill tests (KF1 and Bruce). KF1 is a standard test for the assessment of aerobic and anaerobic energy capacity.[23] The starting speed of the KF1 was 3 km·h^{-1} at a slope of 1% (continuous) for a duration of 2 min, after which the speed increased by 0.5 km·h^{-1} at the end of the third min and after that every 30 sec until volitional exhaustion. During recovery after each test protocol, the subjects walked at 5 km·h^{-1} for 3 min. In the Bruce protocol, the participants started exercising at a treadmill speed of 2.7 km·h^{-1} and an incline of 10% gradient for 3 min. Workloads (speed and inclination) were subsequently increased each 3-minute period in a simultaneous way until volitional exhaustion was reached.[23] Both protocols generated equal cardiorespiratory data as the MetaMax® 3B, which were filtered and averaged on a 5-second basis.

Statistical analysis

Diagnostic accuracy of outcome measures derived from the BAT protocol against the KF1 and Bruce protocols included sensitivity, specificity, false positive (FP) and false negative (FN) values, and the level of positive likelihood ratio (PLR) and negative likelihood ratio (NLR). The outcome was every variable derived from the KF1 and Bruce protocols categorized as 'low' (below the 50th percentile) and 'high' (above the 50th percentile) according to the median value. Such approach has been previously used for soccer players and general population to determine the level of physical fitness.[24,25] Based on the two groups for each variable, we cross-tabulated the values from the MetaMax® 3B portable device and calculated the abovementioned statistical procedures. Sensitivity represented the proportion of individuals with the 'true' positive test, while specificity denoted those with the 'true' negative test. Sensitivity and specificity equations were as follows: sensitivity = (true positives)/(true positives + FN) and specificity = (true negatives)/(true negatives + FP). Individuals categorized in the 'high' group for the KF1 and Bruce protocols, but 'low' for the BAT protocol and *vice versa* represented FP and FN. Likelihood ratios determined the utility of the BAT protocol. PLR was calculated as sensitivity/(1-specificity), while NLR was calculated as (1-sensitivity)/specificity. To examine the discriminatory ability of the ventilatory and metabolic outcomes derived from the MetaMax® 3B portable device to predict the same variables from the KF1 and Bruce protocols, we used receiver operating characteristics (ROC) curves quantified by the area under the curve (AUC). ROC curves analyses were designed to test the discriminatory power. The AUC represented the diagnostic power of a test classified as small (AUC= .55 – .62), moderate (AUC= .63 - .71) and large (AUC> .71). Two-sided values of P were used, and significance was set at P<.05. All the analyses were calculated in Statistical Packages for Social Sciences v.23 (SPSS, Chicago, IL, United States).

Results

Before the examination of diagnostic accuracy of the BAT protocol against the KF1 and Bruce protocols, we determined if a couple dependence was present during the testing procedures, by utilizing a linear-mixed effects model (LMM) with random intercept for couples. Data showed no dependence effect within each couple for $\dot{V}O_{2max}$, as our primary outcome of the study (*F*= 1.533, *P*= .244). As previously stated,[18], the proportion of the participants who reached the cut-off of RER ≥ 1.10 was 20.8% for the BAT protocol and 45.8% and 37.5% for the KF1 and Bruce protocols. Ventilatory and metabolic parameters obtained from the MetaMax® 3B portable device yielded great diagnostic properties in terms of sensitivity and specificity (Table 2). The AUCs exhibited were the largest for the absolute and relative $\dot{V}O_{2max}$, followed by VE and VT. The lowest AUCs were presented for VE/VO_2 and VE/VCO_2. Nevertheless, all AUCs were mostly categorized as 'large'.

Table 3 shows the sensitivity, specificity, FP and FN, and PLR and NLR properties of the ventilatory and metabolic parameters from the BAT protocol against the KF1 and Bruce protocols. Similar to AUCs, the largest sensitivity and specificity properties were generated for the absolute and relative $\dot{V}O_{2max}$. Again, VE/VO_2 and VE/VCO_2 exhibited somewhat lower diagnostic properties. However, all parameters showed PLR greater than 1, indicating that the participants categorized in either 'low' or 'high' categories of the BAT protocol were more likely to be categorized in the same category of the KF1 and BAT protocols. The lowest PLRs were obtained for the VE/VCO_2 in the KF1 protocol (1.68) and VD/VT for the Bruce protocol (1.92). The BAT protocol yielded large to very large correlations with the KF1 and Bruce protocols for both absolute (*R*= .88 and .87) and relative $\dot{V}O_{2max}$ (*R*= .88 and .85), RER (*R*= .78 and .76), VE (*R*= .86 and .79), VT (*R*= .75 and .83), VE/VO_2 (*R*= .81 and .80) and VE/VCO_2 (*R*= .78 and .82), and VD/VT (*R*= .70 and .74).

The linear regression equation to predict the relative $\dot{V}O_{2max}$ from the KF1 protocol was as follows: $\dot{V}O_{2max\text{-}KF1}$ (ml·kg^{-1}·min^{-1}) = −4.305 + (1.100· $\dot{V}O_{2max\text{-}BAT}$) ($R^2$= .77). The slope coefficient between the BAT and KF1 protocols was β= 1.625 with a 95% CI (.90, 2.25), while the intercept coefficient was *a*= −18.43 with a 95% confidence interval (−64.65, 42.13), indicating no

Table 2. Classification of the study participants based on the median values of the KF1 protocol against the BAT protocol.

Study variables	Protocol	AUC (95% CI)	Std. error	Significance
$\dot{V}O_{2max}$-absolute (l·min^{-1})	KF1	.92 (.82 – 1.00)	.053	*P*< .001
	Bruce	.93 (.83 – 1.00)	.050	*P*< .001
$\dot{V}O_{2max}$ -relative (ml·kg^{-1}·min^{-1})	KF1	.94 (.90 – 1.00)	.021	*P*< .001
	Bruce	.95 (.86 – 1.00)	.047	*P*< .001
RER	KF1	.81 (.63 - .99)	.091	*P*= .010
	Bruce	.85 (.69 – 1.00)	.080	*P*= .004
$\dot{V}E$ (l·min^{-1})	KF1	.87 (.70 – 1.00)	.086	*P*= .002
	Bruce	.86 (.69 – 1.00)	.087	*P*= .003
$\dot{V}T$ (l)	KF1	.85 (.70 – 1.00)	.078	*P*= .003
	Bruce	.93 (.83 – 1.00)	.054	*P*< .001
BF (bpm^{-1})	KF1	.84 (.69 – 1.00)	.080	*P*= .004
	Bruce	.88 (.74 – 1.00)	.069	*P*= .002
$\dot{V}E/\dot{V}O_2$	KF1	.84 (.68 – 1.00)	.083	*P*= .005
	Bruce	.76 (.56 – 0.96)	.103	*P*= .033
$\dot{V}E/\dot{V}CO_2$	KF1	.65 (.43 - .87)	.114	*P*= .214
	Bruce	.80 (.60 – 1.00)	.102	*P*= .012
$\dot{V}D$/VT	KF1	.76 (.57 - .96)	.099	*P*= .030
	Bruce	.82 (.66 - .99)	.084	*P*= .014

Note: Ballroom Aerobic Test (BAT).

Table 3. Sensitivity, specificity, FP and FN of the BAT protocol against the KF1 and Bruce protocols.

BAT protocol	Protocol	Sensitivity (%)	Specificity (%)	FP (%)	FN (%)	PLR	NLR
$\dot{V}O_{2max}$ ($l \cdot min^{-1}$)	KF1	83.30	75.00	16.70	25.00	3.33	0.22
	Bruce	91.70	75.00	8.30	25.00	3.67	0.11
$\dot{V}O_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	KF1	95.90	90.70	4.10	9.30	10.31	0.05
	Bruce	91.70	91.70	8.30	8.30	11.05	0.09
RER	KF1	76.90	72.70	23.10	27.30	2.82	0.32
	Bruce	76.90	81.80	23.10	18.20	4.23	0.28
$\dot{V}E$ ($l \cdot min^{-1}$)	KF1	80.00	100.00	20.00	0.00	4.00	0.00
	Bruce	83.30	83.30	16.70	16.70	4.99	0.20
$\dot{V}T$ (l)	KF1	76.90	81.80	23.10	18.20	4.23	0.28
	Bruce	84.60	90.90	15.40	9.10	9.30	0.93
BF (bpm^{-1})	KF1	80.00	71.40	20.00	28.60	2.80	0.28
	Bruce	73.30	88.90	26.70	11.10	6.60	0.30
$\dot{V}E/\dot{V}O_2$	KF1	81.80	76.90	18.20	23.10	3.54	0.24
	Bruce	73.30	88.90	26.70	11.10	6.60	0.30
$\dot{V}E/\dot{V}CO_2$	KF1	66.70	60.00	33.30	40.00	1.68	0.56
	Bruce	81.80	76.90	18.20	23.10	3.54	0.24
$\dot{V}D/VT$	KF1	70.60	85.70	29.40	14.30	4.94	0.34
	Bruce	82.40	57.10	17.60	42.90	1.92	0.31

Note: Ballroom Aerobic Test (BAT), The area under the curve (AUC), sensitivity, specificity, false positive (FP), false negative (FN), positive likelihood ratio (PLR) and negative likelihood ratio (NLR).

proportional bias. Similarly, the linear regression equation to predict the relative $\dot{V}O_{2max}$ from the Bruce protocol was as follows: $\dot{V}O_{2max\text{-}BRUCE}$ ($ml \cdot kg^{-1} \cdot min^{-1}$) = −3.996 + (1.075·$\dot{V}O_{2max\text{-}BAT}$) ($R^2$= .72). The slope coefficient between the BAT and KF1 protocols was β= 1.10 with a 95% CI (.80, 1.30), while the intercept coefficient was a= −1.05 with a 95% confidence interval (−10.17, 9.90).

Discussion

The main purpose of the study was to develop and examine the diagnostic accuracy of the BAT protocol against the KF1 and Bruce laboratory protocols in dancesport athletes performing in standard dance styles. Findings suggest that the ventilatory and metabolic parameters derived from the MetaMax® 3B portable gas analyzer during the BAT protocol yield large to very large sensitivity and specificity properties with the KF1 and Bruce aerobic outcomes. The level of AUC indicates satisfactory discriminative power between 'low' vs. 'high' groups in each parameter with high PLRs and low NLPs.

As far as the author is aware, this is the initial research investigating the creation and reliability of a progressive exam to evaluate aerobic capacity in standard dancesport competitors. Our findings ought to be understood in the context of earlier research. So far, multiple advanced field tests to evaluate aerobic capacity in dance have been suggested and confirmed through more objective methods. A study conducted by Wallmann et al.[9] demonstrated that the API submaximal exercise fitness test had a strong correlation with $\dot{V}O_{2max}$ (R= .89 and .90), along with a technical error of measurement (TEM) of power output = .07 $W \cdot kg^{-1}$ and $\dot{V}O_{2max}$= .71 $ml \cdot kg^{-1} \cdot min^{-1}$. A different dance protocol aimed at ballet dancers showed that the mean squared root (sw2) for the test was 5.01, and the SEE was 6.20 $ml \cdot kg^{-1} \cdot min^{-1}$.[10] A frequently used fitness protocol to assess aerobic capacity is the DAFT, a 5-stage progressive test lasting 4 minutes.[11] A study conducted by Wyon et al.[11] showed that data from the portable telemetric gas analyzer (Cosmed K4 b2, Italy) demonstrated a very strong correlation between HRmax and $\dot{V}O_{2max}$ for the test (R= .91; SEE = 5.60 $b \cdot min^{-1}$). Comparable findings were observed for the HIDT dance protocol, with five individuals (n=5) participating in both the treadmill and dance assessments to evaluate $\dot{V}O_{2max}$.[11] In the treadmill protocol, the average $\dot{V}O_{2max}$ recorded was 46.40 ± 3.60 $ml \cdot kg^{-1} \cdot min^{-1}$, while in the HIDT, the $\dot{V}O_{2max}$ value reached 51.00 ± 6.60 $ml \cdot kg^{-1} \cdot min^{-1}$. A comparison between the treadmill and dance protocols indicated no notable differences in $\dot{V}O_{2max}$.[12] The identical research indicated that the average %HR_{max} was notably less in the HIDT when compared to the treadmill assessment (97.50 vs. 101.00 %), while the accuracy of blood lactate measurements was elevated (HIDT = 6.10 ± 1.90 $mmol \cdot L^{-1}$ vs. treadmill = 6.30 ± 1.70 $mmol \cdot L^{-1}$).[12] The latest SAFD assessment measuring the functional ability of collegiate dancers showed substantial to very substantial correlations with the peak treadmill evaluation for relative $\dot{V}O_{2max}$ (R = .78), HR_{max} (R= .85), blood lactate (R= .72), and rate of perceived exertion (RPE; R= .84), whereas trivial to moderate correlations were observed for time (R= .60) and RER (R= -.12).[13]

Despite the current progressive dance protocols for evaluating aerobic capacity showing acceptable validity compared to objective measures,[9-13] our recently created BAT protocol demonstrated strong correlations with the treadmill test after two protocols (KF1 and Bruce). The unique aspect and distinction of our dance protocols compared to others is that they are tailored specifically for dance couples practicing standard dance styles. This is crucial, as both people must support one another during practice or competition. This implies that comparable fitness levels may be beneficial for performance. Although $\dot{V}O_{2max}$ is generally lower in dancesport athletes in comparison to other athletes,[4-6] the aim of the BAT protocol is to improve the aerobic system and to physiologically prepare them for stress during training and/or competition.

Standard dance styles frequently feature movements defined by sway elements and the interaction of rises and falls, regarded as crucial factors for maintaining or enhancing functional performance in competitive dancesport competitors.[26] Additionally, the intricate figures and quicker tempo during training and competition in standard dance styles cannot be compared to ballet or contemporary dance styles, where movements are frequently executed in static settings, focusing more on aesthetics than on the functional aspects of dance. Consequently, the BAT protocol can act as a method for assessing and monitoring aerobic capacity within the limited group of standard style dance competitors.

This research has its limitations. Initially, a cross-sectional design inhibits our ability to validate causal relationships between field- and laboratory-based testing methods for evaluating aerobic capacity. Second, we omitted HR_{max} and blood lactate measures as indicators of aerobic and anaerobic abilities, restricting our results to data obtained from the MetaMax® 3B and treadmill equipment. Earlier research has demonstrated a significant connection between HR_{max} and $\dot{V}O_{2max}$ [10,11] and sufficient sensitivity in HR_{max} and blood lactate variations after the dance protocol.[27,28] The reasons for not considering these measures were the lack of time and devices for collecting and analyzing blood sampling. Third, a relatively limited sample size may have weakened the validity characteristics of the BAT protocol. Even though we conducted a sample size calculation (for additional details, refer to the ‘Study participants’ section), we cannot rule out the possibility of inadequate statistical power. Fourth, statistical analyses indicated that objectively measured ventilatory and metabolic parameters were split by a median into two groups (low *vs.* high), which could have led to a lack of statistical power and hypothetical significance. Thus, we re-calculated the continuous data and presented with the coefficients of correlation between the BAT and KF1/Bruce protocols and a set of regression equations to estimate predicted $\dot{V}O_{2max}$. Also, previous studies have used the same approach to define the participants with low. vs. high physical fitness levels, based on cardiorespiratory data.[24,25] Ultimately, the BAT protocol was not cross validated in athletes from various dance styles (ballet, contemporary, or Latin-American), which constrains its applicability. The authors indicate that the BAT protocol serves as a legitimate training and performance instrument for assessing aerobic capacity and related factors in dancesport athletes engaged in standard dance styles. Finally, while the tempo was controlled, this freedom introduced potential variability in movement economy and energy expenditure between couples, which could influence the results.

Practical Applications

The practical use of the BAT protocol is shown in creating a brand-new model to assess aerobic capacity and an algorithm for estimating $\dot{V}O_{2max}$ in competitive standard dances within sport-specific activity conditions. This allows for an accurate evaluation of physical and energy demands related to the activity, in contrast to current tests for measuring aerobic capacity. Given that conventional dance styles are frequently identified as high-intensity physical activities requiring both aerobic and anaerobic energy systems for execution, the newly introduced dance protocol could enhance aerobic capacity and improve dance training. Accurate and promptly executed diagnostic methods for evaluating and/or measuring energy capacities in dance are essential to reach primary objectives and foster positive trends toward athletic success.[1,4] On the other hand, data from the BAT protocol could be used in both clinical and coaching environment to test specific aerobic capacity related to dancesport performance. Health-related professionals and strength and conditioning coaches should include the BAT protocol to evaluate, monitor and track cardiorespiratory fitness and to adjust training and choreography regimes for maximal performance output and persistence of high ventilatory and metabolic parameters for future health. However, given the nature of the study, future research should consider establishing the minimal detectable change (MDC), which is critical for coaches to determine if an observed change in performance is a true improvement or simply measurement error.[29] This would improve practical ability of the test and denote whether changes in performance occur intentionally or by chance.

Conclusions

In conclusion, this research demonstrates that the BAT protocol exhibits excellent diagnostic accuracy properties when compared to the KF1 and Bruce protocols. The benefit of the BAT protocol lies in its ability to replicate classical movements from five dance styles while imitating competition environments. The present results have demonstrated sensitivity and specificity characteristics and possible recommendations for overseeing and observing changes in ventilatory and metabolic parameters across various training conditions. The authors propose that this assessment can be incorporated into the dance training regimen during preparatory and competitive phases, as it provides crucial and reliable insights into the correlation between field and laboratory aerobic performance metrics among standard dancesport competitors. As mentioned in the ‘Practical application’ section, MDC should be the next critical step for validating the BAT protocol for practical use. Since it tests the smallest change that is unlikely to be due to the measurement error, evaluating the MDC may be helpful for targeting a ‘real’ change. This can help coaches in planning the target ventilatory and metabolic outcomes to reach high confidence levels and to adjust the training program for enhancing aerobic capacity.

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Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Ethical Committee approval

The Ethical Committee of the Faculty of Kinesiology, University of Zagreb, Zagreb, Croatia; approved the study on the 29th of April 2020 (ethical code number: 77/2020).

Topic

Sport science

Conflicts of interest

The authors have no conflicts of interest to declare.

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Author-s contribution

Conceptualization, T.D.; methodology, T.D.; software, T.D.; validation, T.D.; formal analysis, T.D.; investigation, T.D.; resources, T.D. and D.P.; data curation, T.D.; writing—original draft preparation, T.D., J.R. and D.P.; writing—review and editing, T.D., J.R. and D.P.; visualization, T.D.; supervision, D.P.; project administration, T.D. All authors have read and agreed to the published version of the manuscript.

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