The Development of a High Intensity Dance Performance Fitness Test

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Abstract

While there is currently a validated dance-specific exercise method of measuring aerobic fitness, no such test has been developed to measure high intensity capabilities in dance. The purpose of this study was to initiate an intermittent high intensity dance-specific fitness test. The test was designed to be able to observe changes in heart rate (HR), thereby allowing for a measurement of physical fitness at high intensities. Sixteen professional dancers (4 males and 12 females) volunteered to take part in this study. The fitness test protocol consists of movements that are representative of contemporary dance, and contains exercise and rest periods that mimic the intermittent nature of dance. The participants performed four trials. The physiological variables measured were HR ($b·min^{-1}$) for each one minute bout of the four minute test for all trials, oxygen uptake (VO_2) throughout the test, and end blood lactate (BLa mmol·L) for each trial. In addition, five of the participants undertook a maximal oxygen uptake treadmill test, and the scores obtained were compared with those from the dance test. Results show HR consistency across each one minute bout of the test and across each of the four trials of testing for all participants, indicating that the test is reliable. There was good reliability between bouts of each trial (typical error as % of CV = 1.5), intraclass "r" = 0.8, and good reliability between the four trials (typical error as % of CV = 2.1), intraclass "r" = 0.82. There were no significant differences between the maximal VO_2 and BLa scores established in the treadmill and dance tests, demonstrating validity. Thus, the results of this study indicate that the high intensity dance-specific test is a reliable and valid means of assessing and monitoring the cardiovascular fitness of dancers. The test allows dancers to be assessed within an environment that they are accustomed to (the studio), using a mode of exercise that is relevant (dance), and it is of adequate intensity to be representative of performance.

Regular monitoring of adaptations from any training regimen is advisable so that the effect of that training can be measured and modified as necessary. In dance training, the monitoring of skill and technical improvements often prevails over other concerns; thus, dancers' physiological development and preparation for performance has been somewhat overlooked.

There have been previous attempts at measuring the energy demands of dance and the fitness status of dancers.[1-7] A rise in blood lactate (BLa) above 4 $mmol·L^{-1}$ is an indicator that ATP demand cannot be met solely by aerobic glycolysis and that the proportion of energy derived from anaerobic pathways has increased. Previous research has noted BLa values of 10 $mmol.L^{-1}$ during dance performance.[2] Another method for measuring exercise intensity is via heart rate and oxygen uptake recordings. Cohen and colleagues noted peak HR values of 184 $b·min^{-1}$ and a mean HR of 169 $b·min^{-1}$ during dance performance.[1] The same investigators found that dancers perform at 90% of their maximum HR for short amounts of time. Wyon and colleagues noted that the mean oxygen demand and heart rate of dance performance was significantly greater than that seen during rehearsal and class.[6] Though the dance class reached the same aerobic intensities as performance (55+ $ml·kg^{-1}·min^{-1}$), significantly less time was spent there, and rehearsals rarely exposed the dancer to these intensities. Dance appears to be an intermittent activity that utilizes both the aerobic and anaerobic energy systems.[2-7] In order to ensure that appropriate physiological improvements occur, it is therefore important that dance scientists and educators monitor both the demands of dance performance and dancers' aerobic and anaerobic fitness levels.

Much of the early research in

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these areas, however, has involved either the use of Douglas Bag equipment to measure oxygen demands, or researchers have estimated oxygen uptake (VO_2) values from dance heart rates (HR). Both techniques have drawbacks: in the former, movement restriction was noted by the dancers during their dancing,[3,8] and in the latter, extrapolation of oxygen uptake was based on the principle that the linear relationship between HR and VO_2 established during a steady state lab test holds true for dance. Dance is considered a non-steady-state activity,[2-7] and although the indirect method of predicting VO_2 from HR has been noted as reliable during steady-state activity,[9,10] the opposite is true for dance.[11] This finding led to the development of the Dance Aerobic Fitness Test (DAFT),[12] which is now used by several dance companies and schools to monitor changes in aerobic capabilities across time. To date there is no validated high intensity dance-specific fitness test available that can provide a way of evaluating the ability to dance at the higher intensities representative of stage performance—those that utilize the anaerobic energy systems.

The development of more specific and precise methods of evaluating performance is of interest to many sports scientists. Most physiological monitoring has been undertaken within standardized conditions such as laboratory settings, rather than "in the field." This is to ensure that the tests remain valid, reliable, and objective. However, questions often arise as to the relevance of such tests with regard to specificity. The debate between laboratory and field-testing is on-going; while laboratory tests are more likely to yield accurate results, they may be less representative, and while field tests are more relevant and specific, they have the potential of being less accurate. This predicament has led to the development of activity-specific measuring tools like kayak ergometers and swimming flumes, as well as the invention of the telemetric gas analyzer, which is lightweight, portable, and non-restrictive.

Dancers' anaerobic fitness has been previously measured using the Wingate Anaerobic Test (WAnT), usually involving a cycle ergometer.[4,5] While this is a recognized standard laboratory test, it does not use a mode of exercise that is familiar to dancers. First, dancers are not used to working to volitional exhaustion (probably due to the high skill factor in dance and the fact that choreographers set the intensity by virtue of the choreography).[4] Second, the cycle ergometer is a non-impact mode of exercise that uses specific muscle groups repeatedly, which is again something unfamiliar to dancers. The concept of specificity should be acknowledged, whereby methods of assessment are designed to allow athletes to be tested in an environment with which they are familiar. Today it would be almost unheard of, for example, to test a swimmer on a cycle ergometer or treadmill.

Dance science is a relatively new area of research, and there is a need for more research into dance-specific field tests. The Research Committee and the Standard Measures Consensus Initiative of the International Association for Dance Medicine and Science has been advocating standardized techniques for measuring dancer capabilities. The aim of the present study was to develop an intermittent high intensity dance-specific fitness test. The test was designed to facilitate observation of changes in HR and in the qualitative performance of movement material across time, thereby identifying any physiological developments at high intensities. This research is descriptive in design and based on the following hypotheses:

- There should be reliability in HR between each bout and between each trial of the fitness test;
- There should be reliability in end BLa between each trial of the fitness test; and
- There should be no differences in HR, VO_2, or BLa between the results of the fitness test and a maximal oxygen uptake treadmill test undertaken concurrently by a subset of the participants.

Methods

Dance Test Protocol

A one minute movement phrase was developed over several rehearsals by professional dancers and teachers based at a leading UK dance vocational training institution. They were asked to use movement material that was representative of contemporary dance (sometimes known as modern dance). It was important for the intensity to be similar to the intensity levels previously noted in dance performance.[1,8] This meant that the test tempo/speed, size, and type of movement were taken into consideration. The work to rest ratio was set at 1:2. It was also important to keep the movement phrase as simple as possible to reduce the learning effect across time. The emphasis of the test is therefore physiologically based rather than skill oriented, reducing the effect of movement economy through practice.

The completed test protocol (Table 1) consists of jumps in first and second position, rolls to the floor, weight transference from feet to hands and back to feet, circular springs with an arm pattern, and a parallel jump forward in space using an arm swing. The phrase is completed three times within one minute at a tempo of 106 bpm, and repeated again after two minutes of rest. This sequence occurs four times.

Participants

Following ethical approval from Laban's Ethics Committee, 16 participants volunteered to take part in this study. There were 12 females and 4 males, all professional contemporary dancers with at least three years of full-time training and currently injury free. Participant characteristics can be found in Table 2.

The tests and procedures were fully explained to all participants, who then gave informed consent and completed a medical questionnaire. They were advised that they could withdraw

Table 1 The Dance Fitness Test Protocol

1 minute dancing
2 minute rest
1 minute dancing
2 minute rest
1 minute dancing
2 minute rest
1 minute dancing
Tempo throughout each 1 minute dancing: 106 bpm

from testing at any time should they wish to do so without giving reason or notice.

Procedures

Each dancer performed a prescribed 6.5 minute warm-up, followed by an opportunity to stretch as they wished. The warm-up consisted of walking, skipping, and jogging in a circle, changing direction while incorporating an upper-body mobility pattern. The participants were tested once each day on two, three, or four separate days (2 to 4 trials each) within a two-week period. It was necessary to limit the overall duration of testing to ensure that any changes between trials would be a result of some inconsistency in the test rather than an actual physiological improvement in physical fitness, which could occur from a longer lapse between trials. The test was conducted at the same time each day (early morning), in the same studio, and with the same musical accompaniment and metronome. In nearly all cases the participants performed the test in twos.

Prior to the test all participants were introduced to the tempo and movement phrase by listening to the metronome and "marking" the movements.

Participants were fitted with a heart rate monitor and watch (Polar Accurrex, USA). Heart rate (HR) was calculated across the trials and for the end of each of the four one-minute stages of dancing. Heart rate was also calculated as a percentage of the participant's age-predicted maximum.

Other physiological parameters measured during the test were blood lactate (BLa) and oxygen uptake (VO_2). Blood lactate samples were taken from the earlobe using a Lactate-Pro (Arkray KDK, Kyoto, Japan) within 3 minutes after the last dancing minute of the test. The procedure for blood taking was compliant with the British Association of Sport and Exercise Sciences (BASES) laboratory guidelines.[13] VO_2 was recorded throughout one full testing session for five of the participants using a portable telemetric gas analyser (Metamax 3*b*, Germany).

During the two-week testing period, five of the participants undertook a maximal oxygen uptake (VO_2max) treadmill test to determine whether maximal values established in a standardized lab test were similar to those measured in the dance test (unfortunately not all participants were able to take this test due to other work commitments). The procedures for the VO_2max treadmill test, as well as the criteria for determining whether the participants had reached their maximum capacity during the treadmill test, were taken from the British Association of Sport and Exercise Sciences (BASES) laboratory guidelines.[13] During both the treadmill test and the dance test all participants were given verbal encouragement.

Eight of the participants were performing contemporary dance repertoire during the testing period as part of their work with a contemporary dance company. Their HR and BLa were measured while performing four dance pieces from the company's current five piece repertoire in order to compare this data with that gathered during the high intensity dance test.

Statistical Analysis

Hopkins[14] and Hopkins and colleagues[15] suggested that the main measures of reliability are within-subject random variation, systematic change in the mean, and retest correlation. They further suggested that an adaptable form of within-subject variation is the typical (standard) error of measurement, or the standard deviation of an individual's repeated measurements. This can be expressed as a coefficient of variation (percentage of the mean). In the present study the reliability of HR, BLa and %HR max between bouts and participants were assessed using repeated measures ANOVA and the Bland-Altman test [coefficient of variation (CV) and the percentage change in the mean between trials (%Δmean)].

A repeated measures ANOVA between subjects design with within-subject repeated contrasts was used to detect and analyze a main effect for the relationship between trials. Reliability of the high intensity dance test was calculated by determining the CV and the %Δmean.

Results

The variables measured were mean HR ($b \cdot min^{-1}$) for each bout of all trials, and mean HR and end BLa for each trial (Table 3 and Fig. 1).

The mean BLa at the end of the high intensity dance test for all 16 participants was 5.7 $mmol \cdot L^{-1}$, indicating that the intensity of the test was high

Table 2 Participant Characteristics

Number of Participants (N = 16)	Level of Experience	Age (yr) (SD)	Body Mass Index (SD)
Male (N = 4)	Professional	24.6 ± 0.5	21.9 ± 0.9
Female (N = 12)	Professional	27.8 ± 7.8	20 ± 1.9

Table 3 Mean Heart Rate and Blood Lactate Data for Each Trial (Day) of the 4-Bout Dance Test (see also Fig. 1)

	Trial 1	Trial 2	Trial 3	Trial 4
HR ($b \cdot min^{-1}$)	167 ± 7.98	175 ± 7.6	176 ± 8.2	177 ± 8.2
BLa	5.1 ± 2.01	5.2 ± 2.8	5.9 ± 2.5	6.2 ± 1.4

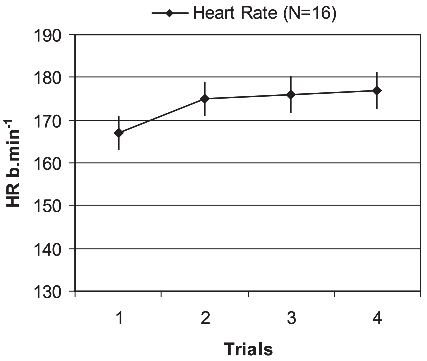

Figure 1 Mean heart rate for all participants (N = 16) across four bouts of each trial.

enough to stress the anaerobic energy pathways (Table 4).

Hopkins[15] and Hopkins and associates[16] suggest that the coefficient of variation be expressed as a percentage of change between trials. Further, percentage changes below 5% between trials are to be considered as reliable. As can be seen in Table 5, the percentage changes in coefficient of variation for HR are within this designated limit (below 5%). The larger variation in BLa as expressed as a percentage of change is due to the slight biological variation seen within the raw data (mean 6.1 ± 2.1) when expressed as a percentage change, exaggerating the variation in scores.

Results show HR consistency across each one minute bout of the test and across each of the four days (trials) of testing for all participants, indicating that the test is reliable. There was good reliability between bouts of each trial (typical error as % of CV = 1.5), intraclass "r" = 0.8, and good reliability between the four trials (typical error as % of CV = 2.1), intraclass "r" = 0.82 (Tables 5 and 6).

Dance Performance

The duration of each of the four dance pieces varied for each individual. The mean BLa values taken at the end of each dance piece were below 4 mmol·L^{-1} (Table 7), indicating that for these participants the dance pieces were not particularly stressing on the anaerobic pathways.

The mean HR across all four dance pieces for the eight participants was 101 b·min^{-1}, and the mean peak HR was 187 b·min^{-1}. Not all dancers were dancing for the whole duration of each piece.

Maximal Oxygen Uptake Treadmill Test

All five participants who undertook the VO_2 max treadmill test met at least three of the four criteria as outlined by BASES[14] for determining VO_2 maximum: Respiratory Exchange Ratio (RER) value greater than 1.1, which indicates a rise in VCO_2 relative to VO_2; a greater shift toward metabolism of the substrate CHO; attainment of age-

Table 4 Mean Heart Rate and Percentage of Age-Predicted Heart Rate Maximum at the End of Each Bout of the Test Across All Trials and Mean Blood Lactate at End of the 4-Bout Dance Test (N = 16)

Bouts/stages of Dance Test	Mean HR (b·min^{-1})	% of HR age-predicted maximum	End Test Blood Lactate (BLa mmol^{-1})
1	167.9 ± 7.3	87	
2	174.4 ± 7.5	90	
3	175.9 ± 8.1	91	
4	175.9 ± 8.1	91	5.7 ± 0.4)
Mean	173.4 ± 3.7	90	

Table 5 Reliability Data for Heart Rate and Blood Lactate

	HR	BLa
Changes in mean	2.54	0.92
Typical error	5.01	1.12
Changes in mean as a %	1.6	17.8
Typical error as a CV%	3.1	21.7

Table 6 Repeated Measures

Repeated measures BLa	
Within subject effect	$F(3,12) = 1.262$; $p > .05$
Within subject contrasts	$F(1,4) = 0.259$; $p > .05$
Repeated measures HR	
Within subject effect	$F(3,54) = 0.5$; $p > .05$
Within subject contrasts	$F(1,18) = 0.015$; $p > .05$

Table 7 Mean (and SD) Blood Lactate at the End of Each of the Four Dance Pieces (N = 8)

	Dance Piece 1	Dance Piece 2	Dance Piece 3	Dance Piece 4
Duration of dance (min)	35-51	101-112	125-144	157-210
Mean BLa (mmol·L^{-1}) (SD)	1.6 (0.4)	3.9 (1.6)	2.3 (1.0)	2.0 (0.4)

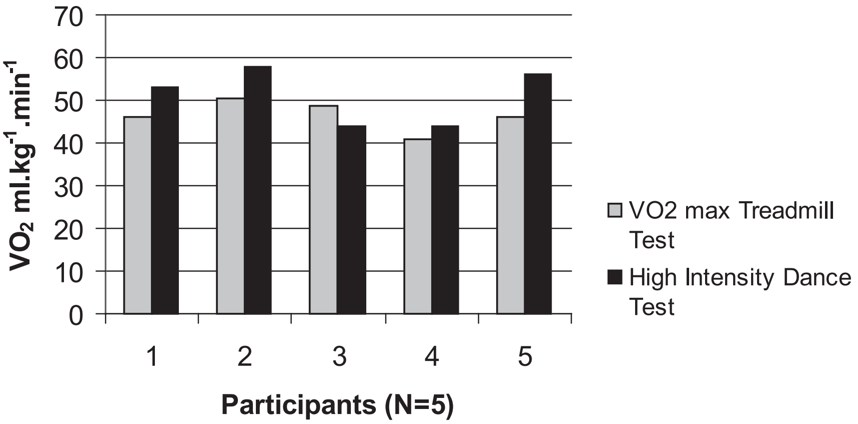

Figure 2 Maximal oxygen uptake during the treadmill test and dance test for five participants.

predicted maximum HR; plateau of no more than 4 ml·kg·min^{-1} of VO_2; or the participant chose to stop. A comparison between maximal oxygen uptake values established during the treadmill test and those observed in the dance test can be seen in Figure 2.

The dancers' mean maximum VO_2 values during the treadmill and VO_2 peak values during the dance test were 46.4 (± 3.6) ml·kg·min^{-1} and 51 (± 6.6) ml·kg·min^{-1}, respectively. These differences were statistically non-significant ($p > .05$), indicating that the dance test was at a maximum intensity for these particular participants. The HR values recorded during the maximal treadmill test and the high intensity dance test were calculated as percentage of the five participants' HRmax. Mean % of HRmax for participants during the treadmill and dance test was 101% and 97.5%, respectively. These differences were statistically significant ($p < .05$). Mean peak BLa recorded during the treadmill and dance test was 6.3 (± 1.7) mmol·L^{-1} and 6.1 (1.9) mmol^{-1}, respectively (Table 8), and these differences were statistically non-significant ($p > .05$).

Table 8 Differences in HR, VO_2 and BLa Between the Treadmill and Dance Tests for Five Participants

Physiological Parameter	Maximal Treadmill Test Mean (SD)	Dance Test Mean (SD)	Statistical Significance
% HRmax b·min^{-1}	101	97.5	p = .02
VO_2 ml·kg·min^{1}	46.4 (3.6)	51 (6.6)	p = .10
BLa mmol·L^{-1}	6.3 (1.7)	6.1 (1.9)	p = .86

Discussion

Cohen and coworkers[1] noted peak HR values of 184 b·min^{-1} and a mean HR of 169 b·min^{-1} during dance performance. The mean HR for all participants during the dance test in the present study was 173 b·min^{-1}. However, absolute HR values should be used with caution, as they do not take into account age-related variances. Cohen and coworkers[1] also found that dancers perform at 90% of their maximum HR, and in this study the mean % of HRmax for all participants was also 90%, indicating that the intensity of the dance test is similar to the intensity previously measured in dance performance. Interestingly, the performance HR data gathered in the current study were from contemporary dance, and previous results show that mean HR values are lower in contemporary dance performance than in ballet (101 b·min^{-1} versus 169 b·min^{-1}), although peak HR values are similar (187.9 b·min^{-1} and 184 b·min^{-1}, respectively).[1] It should be noted that almost all published research in this area has been undertaken with classical ballet performance, and caution must be applied when comparing physiological characteristics within different dance genres. Thus, Cohen's study and this one cannot be matched for intensity, as the dance genres are so different. This further supports the argument for more performance data across dance genres.

Previous research has found that dancers sometimes perform at 80% of their VO_2max,[8] which is at least the case in this study when comparing the dance test with VO_2max treadmill test scores (Fig. 2). During the dance test, those participants who undertook the VO_2 max treadmill test were working at 115%, 115%, 90%, 108%, and 121% of the maximum VO_2max scores on their treadmill tests (Fig. 2). In all but one case, the dancers seemed to push themselves harder when dancing than when running, probably because of their familiarity with the movement. This further substantiates the argument for dance-specific methods of measurement.

A rise in BLa beyond 4 mmol·L^{-1} is an indicator that the demand for ATP cannot be met solely by the aerobic glycolysis, and that the proportion of energy derived from anaerobic pathways has increased.[16] Previous research has noted BLa values of 10 mmol·L^{-1} during a ballet solo[8]; however, again, this was ballet rather than contemporary dance. The mean BLa values recorded for the participants in this study after the dance test were above 4 mmol·L^{-1}, which indicates that the dance test calls upon the anaerobic energy pathways. Mean peak BLa scores recorded after the treadmill and dance test were 6.3 (± 1.7) mmol·L^{-1} and 6.1 (± 1.9) mmol^{-1}, respectively (Table 8). These differences were statistically non-significant ($p > .05$), which further supports the view that the dancers were working at a high intensity during the dance test. In addition, there was no significant difference in the physiological parameters recorded for VO_2 between the treadmill and dance tests, indicating that the dance-specific performance test for this group of dancers was set at an adequate intensity to be considered as a high intensity test. The significant difference in HR between the treadmill and dance tests may relate to the dancers being less anxious when dancing (lower HR) than when treadmill running (higher heart rate), even though intensities between the two were similar (as shown in the VO_2 and BLa).

The development of the dancer's physical fitness seems to be more a byproduct of skill acquisition than focused fitness training. Enhancement of the aerobic system, at least, is required, probably pre-rehearsal, to allow dancers the physiological capability to cope with the stresses placed upon them during performance. Also, as previous research has shown, dancers are required to perform at high intensities, calling upon the anaerobic energy pathways.

It should be noted that while the dance test may be maximal for most, dancers who are particularly fit and whose anaerobic threshold is at a higher percentage of their VO_2max may not be working maximally during the dance test, and may not produce BLa values above the 4 $mmol \cdot L^{-1}$ point. Interestingly, the dance performance mean BLa values calculated in the current study did not exceed the 4 $mmol \cdot L^{-1}$ threshold. The challenge with assessing contemporary dance is that it is so diverse, that while one study may show contemporary dance performance to be high in intensity another may show the opposite to be true. It would be fair to suggest, therefore, that contemporary dancers need to be both aerobically and anaerobically fit in order to be prepared for the many different demands of the genre. However, so long as the dance test is set at an appropriate intensity level to meet the physiological demands of performance, the test should be suitable. It was not the aim of this study to devise a maximal test, such as the Wingate Anaerobic Bike Test. Rather, the aim was to devise a test that was of an intensity that is representative of previously reported dance performance in order to help evaluate whether a dancer is physiologically fit enough to perform. As mentioned earlier, previous research has shown a discrepancy between class, rehearsal, and performance in terms of cardiovascular demands.[6] A dance test such as this can be used for both testing and training purposes as part of a dancer's training regimen to ensure that those higher intensity demands are addressed. Observations can be made across time not only through quantitative means such as HR, but also through qualitative means, such as the observation of movement proficiency.

One of the main reported causes of injury in dance is fatigue, and a high level of physical fitness will delay the onset of fatigue.[17,18] A test of this kind may help provide information about a dancer's physiological capabilities through relevant and applicable means. As a result of this information more effective dance training programs may be devised to help reduce the risk of injury.

Limitations and Future Research

The main limitation of this study is the low number of participants for some of the tests. Unfortunately, not all participants were able to undertake the maximal oxygen uptake treadmill test. Other limitations relate to the administration of the dance test; presently only its designers have taught the test to participants, and possible differences will have to be monitored when the test is administered by others. The effects of learning the dance test from film and the use of subjective movement observation criteria could be investigated in the future.

Professional dancers were used for this study, and it would be interesting to compare professional dancers to novice dancers so as to ensure that changes in the performance of the dance test across time are due to physiological improvements rather than the learned skill effect.

There is an argument for dance genre-specific fitness tests. Given that the research in sports science recommends activity-specific testing techniques in sport, perhaps the diversity shown between dance genre styles may also warrant genre-specific ways of assessing physical fitness in dance. The extent to which this present contemporary dance test is applicable to dancers in classical ballet or jazz, for example, is therefore questionable.

Finally, supplementary fitness training is now being recommended in dance training to prepare the dancer for the demands of rehearsal and performance.[19,20] What is unknown is whether fitter dancers are better dancers. Future research could focus on finding ways to correlate fitness levels with technical and performance outcomes, thereby combining the functional with the aesthetic.

Conclusion

The new high intensity dance performance fitness dance test looks feasible, and promises to yield accurate results in measuring physiological capabilities at high intensities through contemporary dance. The test allows dancers to be assessed within an environment they are used to (the studio), with a mode of exercise that is relevant (dance), and at an adequate intensity to be representative of some contemporary dance performance.

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