An Accelerated Step Test to Assess Dancer Pre-season Aerobic Fitness

Shaw Bronner, Ph.D., P.T., O.C.S., and Sara Rakov, D.P.T.

Abstract

As the technical performance demands of dance increase, professional companies and pre-professional schools are implementing pre-season screenings that require an efficient, cost effective way to measure dancer aerobic fitness. The aim of this study was to assess an accelerated 3-minute step test (112 beats·min^{-1}) by comparing it to the well-studied YMCA step test (96 beats·min^{-1}) and a benchmark standard, an incremental treadmill test, using heart rate (HR) and oxygen consumption (VO_2) as variables. Twenty-six professional and pre-professional dancers (age 20 ± 2.02 years) were fitted with a telemetric gas analysis system and HR monitor. They were tested in the following order: 96 step, 112 step, and treadmill test, with rest to return to baseline heart rate between each test. The step and treadmill tests were compared using Intra-class Correlation Coefficients [ICC (3,k)] calculated with analysis of variance ($p < 0.05$). To determine whether there was a relationship between peak and recovery HR (HR_{peak}, HR_{recov}) and VO_2 (VO_{2peak}, VO_{2recov}) variables, Pearson product moment correlations were used. Differences due to gender or group (pre-professionals versus professionals) were explored with MANOVAs for HR_{peak}, VO_{2peak}, HR_{recov}, VO_{2recov}, and fitness category. The 112 step test produced higher HR_{peak} and VO_{2peak} values than the 96 step test, reflecting a greater workload ($p < 0.001$). For HR_{peak}, there were high correlations ($r = 0.71$) and for HR_{recov}, moderate correlations ($r = 0.60$) between the 112 step test and treadmill test. For VO_{2peak} and VO_{2recov}, there were moderate correlations between the 112 step test and treadmill test ($r = 0.65$ and 0.73). No differences between genders for VO_{2peak} values were found for either step test, but males displayed lower HR_{peak} values for both step tests and higher VO_{2peak} values during the treadmill test ($p < 0.001$). Recovery HR was lower in males for the 96 and 112 step tests ($p < 0.05$). This was reflected in higher fitness scores. There were no differences between groups in any of the variables when only females were compared. For the 112 step test, correlations between HR_{peak} and HR_{recov} were high ($r = 0.85$), and correlations between HR_{peak} and fitness category were very high ($r = 0.98$). It is concluded that the 112 step test provides an efficient, acceptable tool for testing dance populations, though further testing in larger groups of dancers representing a diverse range of genres and training levels is needed.

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The technical demands of dance performance have increased over the years, requiring greater general fitness to meet the requisite skill requirements. Dance medicine health professionals and scientists have strived to assist dancers in meeting these demands through screening of physiological parameters, such as aerobic fitness, strength, and flexibility.[1-14]

Pre-season screening of groups of dancers is becoming a standardized annual practice across professional companies and universities.[2,14-19] The focus of a pre-season screen is to detect red flags indicating potential health problems and to assess whether each dancer has an acceptable level of preparedness to begin rehearsals or pre-professional training.[17,20,21] To be accepted by professional companies, pre-season screens must also be efficient. Currently, the Dance/USA post-hire health screen allows only 20 minutes in total *per* professional dancer for the assessment of medical history, vital signs, fitness, and other physiologic measures. Hence, there is a need for a simple, short test of aerobic fitness that can be used in “field” settings, such as dance studios.

Maximal oxygen uptake (VO_2 max) is related to the intensity of physical work capacity and is accepted as the criterion indicator of cardiorespiratory fitness and aerobic performance.[22] Generally, VO_2 max is determined using one of a number

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of standardized graded exercise tests with treadmills—including incremental Bruce, Balke, or ramp treadmill protocols—or equivalent cycle ergometers.[23] These tests are impractical for testing large groups of participants, as direct measurement of VO_2 max is technically demanding and requires access to both exercise equipment (i.e., treadmill or cycle) and expensive indirect calorimetry equipment to measure gas exchange. Measuring maximal work may not be safe for individuals with exertional dyspnea, chest pain, or discomfort associated with exercise.[21] Maximal tests may also not be convenient for participants, such as professional dancers, who are rehearsing for many hours on the same day as testing and cannot compromise their work.

Another indicator of cardiorespiratory fitness is heart rate recovery (HR_{recov}): how HR declines from either maximal or submaximal exercise to resting levels.[24] HR_{recov} is strongly correlated with VO_2max; more rapid HR_{recov} is found in athletes with higher VO_2max.[25-27] Heart rate recovery is a simple, inexpensive measurement that can be employed during mass screenings.

Step tests were introduced as a practical, low cost way to test the fitness of large numbers of individuals in field settings. Their aim was to determine heart rate response and recovery to a submaximal workload. Step tests have been extensively evaluated against maximal tests to determine their reliability and validity and to ascertain their ability to classify the general fitness of large groups of adults and adolescents.[28-42] Single stage submaximal step tests include the YMCA,[43] Canadian,[44] Queens College,[34] and Harvard [45] variations. Additionally, there are height adjusted and multistage step tests.[32]

Alternative field tests include walking or running for either a specified distance (e.g., Rockport 1.0 mile walk test and Cooper 1.5 mile run test) or time (e.g., 12-minute walk-run), but these options require large open spaces, such as tracks or parks. They are time consuming and generally not practical in the urban location of most dance studios. Dance-specific fitness tests have been developed for ballet and contemporary dancers, but they can be lengthy, entailing five stages of testing over 20 min.[9,12,46]

Considerations in favor of step testing are that the equipment used is portable and has no maintenance or recalibration requirements, the test can be conducted indoors in small spaces, and stepping is a familiar task that need not be learned.[44] Reported stepping rates range from 72 to 140 beats·min^{-1}, step heights range from 0.15 to 0.51 m, and duration of testing from 3 to 10 min.[33,36,47] Although it has been found that performance efficiency is independent of step height,[48] it is important to select a height that does not create a bias against the performance of shorter or heavier individuals, cause undue stress to the knees, or induce local muscle fatigue.[33] It is also important to select a test that is relatively brief, as screening time tends to be limited, and to choose a measure that is not exhaustive, as dancers often must return to rehearsal or technique class ready to participate. The YMCA 3-minute step test (also known as the Kasch step test), developed for mass screening of adults,[33] uses a 0.305 m step at 96 beats·min^{-1}.[43] For the current study, we increased the step rate to allow us to test an athletic dance population and to differentiate between individuals with respect to HR_{recov}.

The purpose of this study was to compare our accelerated step test (112 beats·min^{-1}) to the 96 beats·min^{-1} YMCA step test and a maximal treadmill test in dancers. We hypothesized the following: 1. the accelerated step test would produce a higher peak HR (HR_{peak}) and peak VO_2 (VO_{2peak}), reflecting a greater workload than the YMCA step test; 2. the correlation between HR_{peak} and 1-minute HR recovery (HR_{recov}) for each step test would be high; 3. the relationship between HR_{peak}, VO_{2peak}, HR_{recov}, and $VO_{2\,recov}$ variables for the submaximal step test and maximal treadmill test would be acceptable; and 4. the percent (%) error of predicted VO_{2peak} compared to the measured treadmill VO_{2peak} based on HR_{recov} from the 112 step test would be less than error based on HR_{recov} from the 96 step test.

Methods

Participants

Twenty-six dancers (21 females, 5 males, age 20 ± 2.02 years) voluntarily participated in this study (Table 1). An *a priori* power analysis for a repeated measures design with three tests using one group with a moderate effect size resulted in a sample size of 15. When a second group became available, we conducted a second power analysis and determined that a total sample size of 20 was necessary for a moderate effect size. Dancers were either currently enrolled in a pre-professional collegiate dance program or working for a professional modern dance company. Both groups trained primarily in Horton and ballet techniques. At the time of testing, participants averaged 26.36 ± 9.43 hours of dance per week, including daily technique class(es) and rehearsals. Participants had an average of 11.5 ± 3.43 years of dance training. Exclusion criteria included any musculoskeletal injury resulting in absence from dance activity during the previous 2 weeks. Each participant provided written informed consent, and the study was approved by the university Institutional Review Board.

Instrumentation

Participants wore workout clothing and sneakers and were fitted with a telemetric gas analysis system (K4b^2 Cosmed Inc., Rome, Italy), comprised of a small metabolic analyzer, battery pack, and facemask, and a chest strap heart rate (HR) monitor (Polar Inc., Lake Success, NY). The facemask was attached to a turbine flowmeter that allowed for real-time collection of VO_2 values. The K4b^2 unit (~925 g) was strapped to the participant's shoulders and torso throughout the exercise bout, using the manufacturer's harness. The K4b^2 has demonstrated acceptable reliability and validity.[49,50] It was calibrated according to the manufacturer's instructions

Table 1 Subject Characteristics

Group	Gender	Age (yrs) *	Height (cm)	Mass (kg)	Resting HR (beats·min^{-1})	Resting VO_2 (ml·kg^{-1}·min^{-1})	Yrs dance training	Hrs dance / wk*
Pre-prof	14F	19.57 ± 1.69	166.06 ± 9.25	61.65 ± 10.43	76.79 ± 11.99	3.54 ± 0.97	11.0 ± 3.7	21.46 ± 8.64
Prof	5M	22.80 ± 2.05	176.34 ± 6.07	71.47 ± 8.20	78.31 ± 17.49	3.25 ± 0.82	12.8 ± 2.8	35.0 ± 0.00
	7F	20.57 ± 1.27	165.27 ± 4.30	52.81 ± 2.52	66.60 ± 7.74	3.85 ± 1.24	11.6 ± 3.6	30.0 ± 8.66
Total	26	20.46 ± 2.02	167.82 ± 8.54	61.16 ± 10.48	75.78 ± 12.87	3.41 ± 0.68	11.5 ± 3.43	26.36 ± 9.43

*Differences between pre-professional and professional groups. Age: $p < 0.01$; Hrs dance/wk: $p < 0.001$. Abbreviations: Heart rate, HR; oxygen uptake, VO_2; Years, Yrs; week, wk; Pre-professional. Pre-prof; Professional, Prof.

prior to each testing session. During testing, metabolic values such as VO_2 (mL·min^{-1}) and carbon dioxide production (VCO_2: mL·min^{-1}) and HR (beats·min^{-1}) were monitored continuously and recorded using K4b^2 breath-by-breath analysis. Both step tests were conducted using a 12" step (0.305 m) and a metronome to maintain cadence. A Nautilus T916 Commercial Treadmill (Nautilus, Inc., Vancouver, WA) was used for the incremental treadmill test.

Protocol

Participants were seated in a chair for 10 minutes to obtain baseline resting metabolic and HR values before testing. In order to allow for sufficient HR_{recov} and to conduct the testing period in the most efficient manner, participants were tested in the following order: 96 step, 112 step, and incremental treadmill test. For the YMCA test and the subsequent accelerated step test, participants were instructed to "step up, up, down, down" in tempo with the metronome and were informed of time at each 1-minute interval. Immediately upon completion of each step test, participants were seated for a 10 minute recovery period. Seated recovery was chosen as this is the method commonly used in step test screening. If any participant's HR did not return to within 5 beats of his or her resting HR in the allotted time, the recovery period was extended until this was achieved before beginning the next test. Participants were monitored for any signs of orthostatic hypotension during all recovery periods.

The final test was an incremental treadmill exercise test to volitional fatigue. All participants were familiar with running on treadmills. Anecdotal experience that participants of short stature struggle with higher inclines and that dancers have problems with certain running protocols were important considerations in selecting this incremental protocol.[8]

The initial exercise level was 6.44 km·h^{-1} at an incline of 5%. Speed and incline were increased every 2 minutes in alternating increments of 1.61 km·h^{-1} or 2% incline. After 4 minutes, speed was increased by alternating increments of 2.41 km·h^{-1} or 2% incline until the participant indicated volitional fatigue. Criteria for termination were achievement of any two of the final criteria: HR ≥ 95% of predicted maximal HR (based on the formula 220 – age), respiratory exchange ratio (RER) > 1.10 for three consecutive readings, plateau in $VO_{2\ peak}$ values, or volitional signs of fatigue.[51-53] Heart rate, oxygen consumption ($VO_{2\ peak}$), carbon dioxide production (VCO_2), and respiratory exchange ratio (RER) were determined continuously for 10 minutes before, throughout, and 10 minutes following the step and treadmill exercise testing.

Data Analysis

Post testing, data were downloaded from the K4b^2 and exported into Microsoft Excel 2010 for individual and group analyses. Data were expressed as 10-second moving averages after applying a smoothing function by averaging the breath-by-breath readings over that time period. Participants were assigned a fitness category for each step test based on age, gender, and 1-minute HR_{recov} according to the YMCA step test guidelines.[43] The seven-category interpretation is 0 = Excellent, 1 = Good, 2 = Above Average, 3 = Average, 4 = Below Average, 5 = Poor, and 6 = Very Poor. For example, for males between 18 to 25 years, "Excellent" is HR_{recov} < 79 beats·min^{-1}, "Good" is HR_{recov} between 79 to 89 beats·min^{-1}, and so forth.

Mean (±SD) values were calculated for participant demographics, and group comparisons were made with two-tailed t-tests. Mean (±SD) values were calculated for peak and 1-minute recovery HR, VO_2, and RER for gender and group (pre-professionals versus professionals). Comparisons were made between the step and treadmill tests using Intraclass Correlation Coefficients (ICC 3,k) (SPSS 16.0, IBM Corp, Armonk, NY) calculated with analysis of variance (ANOVA) for HR and VO_2 variables.

To determine whether there was a relationship between within-test peak and recovery HR and VO_2 variables, Pearson product moment correlations were used. Correlations ranging from 0.50 to 0.69 were considered moderate, from 0.70 to 0.89 high, and from 0.90 to 1.00 very high.[54] To determine whether there were differences due to gender or group, MANOVA was conducted for HR_{peak}, VO_{2peak}, HR_{recov}, and VO_{2recov} for each of the three tests and for fitness category for the two step tests.

Predicted VO_2max was calculated for each step test using the McArdle Queens College step test formula (women: $VO_2max = 65.81 - 0.1847[HR_{recov}]$, and men: $VO_2 max = 111.3 - 0.0.42[HR_{recov}]$).[55] Percent error of predicted VO_2max/measured treadmill VO_{2peak} was calculated and compared for the two step tests using a paired one-tailed t-test. Significance was defined as $p \leq 0.05$ for all tests.

Results

There were differences in age and hours of dancing per week between pre-professionals and professionals ($p \leq 0.01$ and 0.001, respectively: Table 1). There were no differences in height, mass, years of dance training, resting HR, or VO_2.

All subjects were able to complete the treadmill test to VO_{2peak}. Mean ±SD values for peak and 1-minute recovery HR, VO_2, and RER during the three exercise tests are seen in Table 2. Differences between tests were significant for all peak test variables ($p \leq 0.001$). As expected, there was an increase in mean HR_{peak} from the 96 to the 112 beats·min^{-1} step test and from the 112 step test to the incremental treadmill test. This was also seen in the VO_{2peak} and RER_{peak} values. For HR_{peak}, there were moderate correlations (ICC [3,k] = 0.68) between the 96 beats·min^{-1} step test and treadmill test and high correlations (ICC[3,k] = 0.71) between the 112 beats·min^{-1} step test and treadmill test ($F[1,24] = 177.67$, $p < 0.001$). For VO_{2peak}, there were moderate correlations (ICC [3,k] = 0.65) between the 96 step test and treadmill test as well as between the 112 step test and treadmill test ($F[1,24] = 116.21$, $p < 0.001$).

There were differences between all tests in 1-minute recovery HR, VO_2, and RER ($p < 0.001$) and between the step tests in fitness categories ($p < 0.001$, Fig. 1). At 1-minute recovery, mean values for HR, VO_2, and RER were lowest in the 96 step test, followed by the 112 step test and then the treadmill test. For HR_{recov}, there were moderate correlations (ICC[3,k] = 0.56 and 0.60) between the 96 step test and treadmill test and the 112 step test and treadmill test, respectively ($F[1,24] = 174.54$, $p < 0.001$). For VO_{2recov}, there were moderate correlations between the 96 beats·min^{-1} step test and treadmill test and high correlations between the 112 step test and treadmill test, respectively (ICC[3,k] = 0.68 and 0.73; $F[1,24] = 60.34$, $p < 0.001$).

Males displayed lower HR_{peak} values for both step tests compared to females ($F[24,1] = 17.013$, $p < 0.001$ and $F[1,24] = 18.208$, $p = 0.00$), but not for the incremental treadmill test. There were no differences between genders for VO_{2peak} values for either step test. Males displayed higher VO-

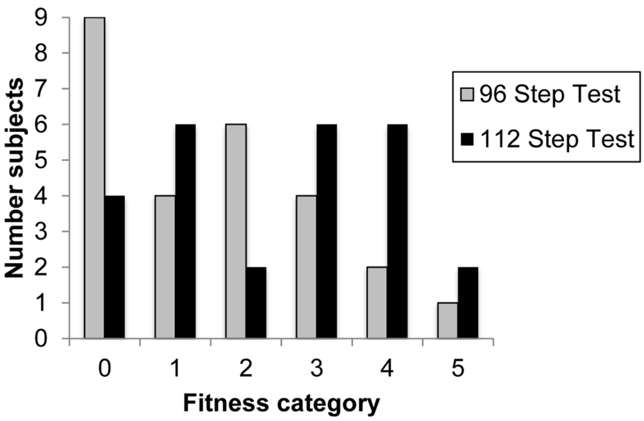


Figure 1 Number of individuals per fitness category in 96 Step Test and 112 Step Test. Based on the YMCA fitness categories, the 112 BPM Step Test resulted in a more even distribution among the categories.

Table 2 Heart Rate and VO_2 Peak and Recovery Values

Test	HR_{peak} (beats·min^{-1})	VO_{2peak} (ml·kg^{-1}·min^{-1})	RER_{peak}	$HR_{recovery}$ (beats·min^{-1})	$VO_{2recovery}$ (ml·kg^{-1}·min^{-1})	$RER_{recovery}$
96 (beats·min^{-1})						
Males	122.00 ± 12.78	37.27 ± 6.34	0.98 ± 0.23	77.40 ± 12.11	13.34 ± 3.62	1.00 ± 0.07
Females	153.27 ± 15.81	34.49 ± 4.54	0.93 ± 0.90	100.20 ± 16.62	13.85 ± 2.66	1.08 ± 0.14
Total	147.31 ± 19.65	35.03 ± 4.92	0.94 ± 0.12	95.82 ± 18.12	13.76 ± 2.79	1.06 ± 0.13
112 (beats·min^{-1})						
Males	136.72 ± 14.59	41.31 ± 7.13	1.01 ± 0.18	82.32 ± 4.26	15.13 ± 2.38	1.00 ± 0.07
Females	168.20 ± 14.88	39.36 ± 5.28	0.99 ± 0.10	109.29 ± 17.91	15.71 ± 3.26	1.17 ± 0.19
Total	162.15 ± 19.27	39.74 ± 5.57	1.00 ± 0.12	104.10 ± 19.42	15.60 ± 3.08	1.09 ± 0.16
Treadmill						
Males	184.72 ± 15.15	66.19 ± 5.73	1.20 ± 0.22	136.56 ± 17.98	23.85 ± 2.84	1.20 ± 0.45
Females	192.69 ± 9.29	51.27 ± 8.51	1.12 ± 0.12	143.98 ± 14.00	20.92 ± 4.52	1.25 ± 0.23
Total	191.15 ± 10.77	54.14 ± 9.96	1.13 ± 0.14	142.55 ± 14.74	21.49 ± 4.36	1.17 ± 0.27

Abbreviations: Heart rate, HR; oxygen uptake, VO_2; respiratory exchange ratio, RER.

Table 3 Fitness Categories

Category	96 Step Test	112 Step Test
Gender		
Male	0.40 ± 0.89*	0.80 ± 0.45†
Female	1.86 ± 1.49	2.76 ± 1.58
Group without males		
Pre-professional	2.14 ± 1.61	3.07 ± 1.54
Professional	1.29 ± 1.11	2.14 ± 1.58
Total	1.86 ± 1.49	2.76 ± 1.58

*Gender 96 Step Test: $p = 0.049$; †Gender 112 Step Test: $p = 0.012$

$_{2peak}$ values during the incremental treadmill test ($F[1,24] = 13.652$, $p = 0.001$]). Males also exhibited more rapid HR_{recov} for the 96 and 112 step tests ($F[1,24] = 8.248$, $p = 0.008$ and $F[1,24] = 10.868$, $p < 0.03$]), but there were no gender differences between males and females for the incremental treadmill test. There were also differences between genders for fitness categories in the 96 and 112 step tests, with males demonstrating greater fitness scores ($F[1,24] = 4.308$, $p = 0.049$ and $F[24,1] = 7.371$, $p = 0.012$ respectively, Table 3). There were no differences between genders for VO_{2recov} values in any of the tests. Due to the gender differences and because there were no males in the pre-professional group, group data were analyzed with males removed. There were no differences between groups for any of the variables.

Pearson correlations between HR_{peak} and 1-minute HR_{recov} were high for the 96 step test ($r = 0.87$) and 112 step test ($r = 0.85$), with 75% and 72% of variance in the recovery variable explained by the peak variable (Fig. 2A and B). Correlations between HR_{peak} and 1-minute HR_{recov} were moderate for the incremental treadmill test ($r = 0.65$), with 43% of variance in the recovery variable explained by the peak variable (Fig. 2C). The relationship of HR_{recov} to fitness category was very high for both the 96 step test ($r = 0.95$) and 112 step test ($r = 0.98$), with 92% and 96% of variance in the recovery variable explained by the fitness category (Fig. 3).

As a predictor of treadmill HR_{peak}, Pearson correlations were moderate for the 96 step and 112 step HR_{recov} and treadmill HR_{peak} ($r = 0.60$ and 0.58, respectively). Percent error of predicted VO_2max compared to the measured treadmill VO_{2peak} was only 4% based on HR_{recov} from the 112 step test (51.60 versus 54.14 $ml \cdot kg^{-1} \cdot min^{-1}$), while percent error was 9% based on HR_{recov} from the 96 step test (48.11 versus 54.14 $ml \cdot kg^{-1} \cdot min^{-1}$: $p < 0.05$).

Discussion

The aim of the current study was to compare an accelerated step test (112 $beats \cdot min^{-1}$) to the well-studied YMCA step test (96 $beats \cdot min^{-1}$) and

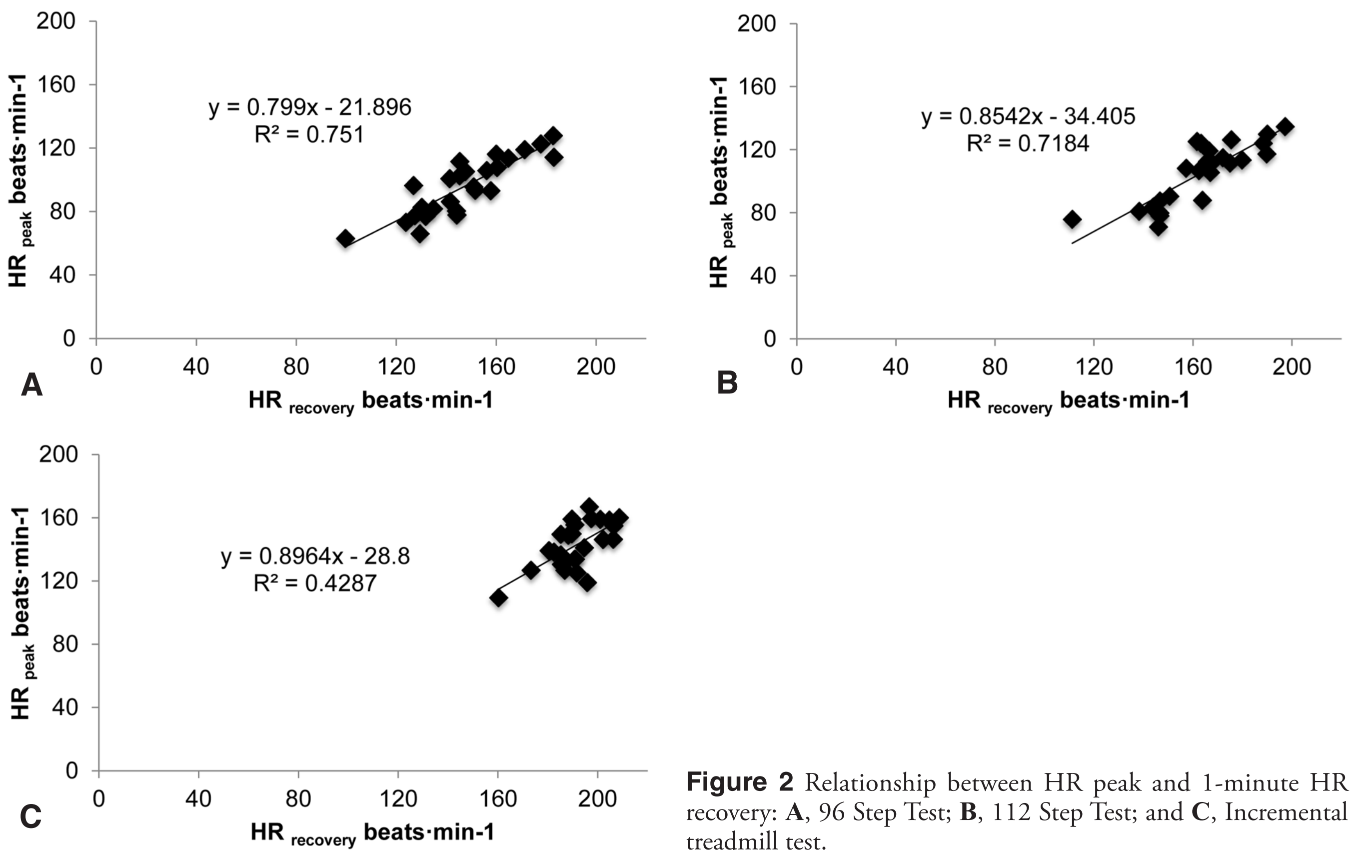
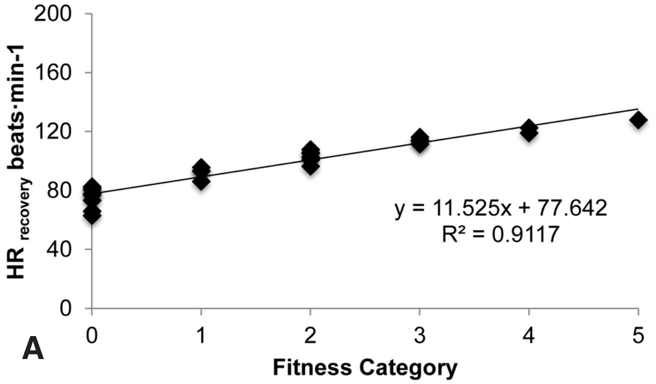


Figure 2 Relationship between HR peak and 1-minute HR recovery: **A**, 96 Step Test; **B**, 112 Step Test; and **C**, Incremental treadmill test.



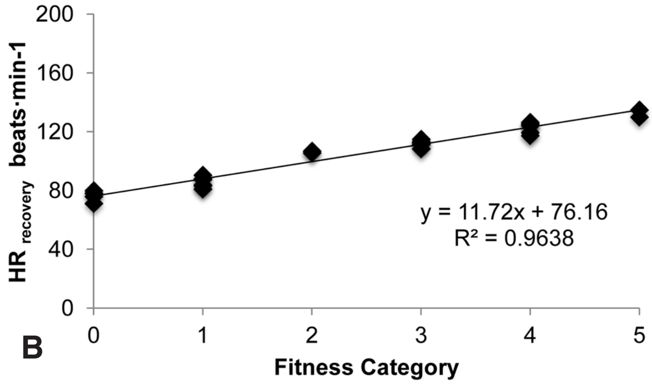


Figure 3 Relationship between 1-minute HR recovery and Fitness Category: **A**, 96 Step Test; and **B**, 112 Step Test.

a benchmark standard, an incremental treadmill test, using HR and oxygen consumption variables. All four of our hypotheses were supported. The 112 step test provoked higher HR_{peak} and VO_{2peak} than the YMCA step test, reflecting a greater workload. Correlations of HR_{peak} and HR_{recov} were high, and correlations between HR_{peak} and fitness category were very high in both submaximal step tests. There were moderate correlations between the 96 step and treadmill and high correlations between the 112 step and treadmill tests for both HR_{peak} and HR_{recov} variables. The 112 step test had greater power to distinguish differences between individuals compared to the 96 step test, finding differences in HR_{peak} and HR_{recov} variables due to gender. The percent error of predicted VO_2max compared to the measured treadmill VO_{2peak} based on HR_{recov} from the 112 step test was less than error based on HR_{recov} from the 96 step test. Therefore, the 112 step test provides an efficient, acceptable tool for testing an athletic dance population and is able to differentiate between individuals with respect to HR variables.

Heart Rate Variables

Heart rate has a positive relationship to energy expenditure during physical activity and can serve as an accurate indirect measure to evaluate metabolic demand.[56] The 1-minute HR_{recov} variable represents the fast recovery phase, with more rapid recovery indicating individuals with a higher aerobic capacity.[26] The use of HR_{recov} to estimate aerobic fitness does not require prediction of VO_2max, as HR_{recov} has demonstrated a strong relationship with training in steady state, moderate and high intensity exercise, and intermittent exercise.[25,56-58] Furthermore, it is important to bear in mind that the purpose of the step test is not to predict VO_2max, as it is a submaximal test. Rather, HR_{recov} is used as a secondary standard of aerobic fitness.[33] Nonetheless, the ability of HR_{recov} from the 112 step test to predict VO_2max using the McArdle formula was compelling when compared to the treadmill VO_{2peak}.

Aerobic Testing in Dancers

Various dance-specific fitness tests have been developed and tested.[9,12,46,59] The argument for using such tests is that dance is an intermittent activity and therefore using a steady state activity to test aerobic fitness is not appropriate. The arguments against using dance-specific fitness tests are that a given test may only be appropriate for one dance form (e.g., modern dance or ballet), they require a familiarization period, and can be lengthy (up to 20 min).[9,12] While HR during dance-specific testing has been validated, HR_{recov} is not addressed. Although the accelerated 112 step test does not capture nuances of capacity and endurance in the manner of the Dance Specific Aerobic Fitness Test, or DAFT, a 20 minute test is not viable for a mass screen with strict time limits. The Taskforce on Dancer Health within Dance/USA, an organization of professional dance companies in the United States and Canada, has developed a standardized, annual post-hire health screen that is now used by more than 30 companies. However, because screens are conducted during work hours, it only allocates 20 minutes *per* dancer for the assessment of medical history, vital signs, fitness, and other physiologic measures, with an additional 10 minutes for counseling about the screen findings.[18,20] HR_{recov} is an important parameter of fitness, and the 112 beat step test is sensitive enough to discern differences between individuals in this regard. Future studies will determine normative values for different levels of dance training and ascertain changes following exercise prescription.

A maximal treadmill test may be employed to ascertain the fitness level of a dancer with respect to other measures, such as dance-specific tests or step tests,[9,29,32,41,44,60] to establish the relative oxygen uptake requirements of dance activity (performance, rehearsal, or technique class),[4,10,61] or to compare the fitness of dancers with respect to dance styles, training, and other athletes or controls.[3,62-67] The relationship between HR and VO_2 is linear during steady state exercise[57]; however, the relevance of this relationship has been questioned when applied to dance.[9,68] Dancing is intermittent and variable, but it does require high intensity intervals of activity that may require HRs near those of age-predicted maximum. Increasingly in today's choreography, those high intensity periods may be prolonged for up to 20 to 30 minutes.[2]

Step tests use a submaximal effort and are assessed via HR. Maximal oxygen uptake in a maximal test and HR_{peak} or VO_{2peak} in step tests are not assumed to test the same aspect of cardiorespiratory function. Participant responses to the 112 step test demonstrated that this accelerated test provided sufficient intensity such that HR_{peak} and HR_{recov} results were highly and moderately correlated, respectively, with those of the treadmill test. Generally, correlations were higher for all comparisons between the 112 step and treadmill test than between the 96 step and treadmill test.

The relationship between HR_{peak} and HR_{recov} showed high correlation for both step tests, compared to only a moderate correlation between HR_{peak} and HR_{recov} for the treadmill test. More than 70% of the variance was explained by the HR_{peak} and HR_{recov} relationship in the step tests but only 43% in the treadmill test. The lower variance of the HR_{peak} to HR_{recov} relationship in the treadmill test can be explained by the longer recovery period required by the maximal test. Extent of variance explained was even greater when the relationship between fitness category and HR_{recov} was calculated in the 96 and 112 step tests (92% and 96%, respectively).

More importantly, if HR_{recov} from a steady state submaximal effort is an acceptable secondary standard of aerobic fitness, then step tests provide a reliable method for differentiating between individuals and levels of training.[33] Our findings of gender differences in HR_{recov} suggest that this was particularly the case for the 112 step test. We also found differences between genders in fitness category for both the 96 and 112 step tests. The fitness categories stratify by age and gender, yet we still found a gender effect, which suggested that there were true differences in HR responsiveness and recovery between female and male dancers.

Incremental Treadmill Test

The incremental protocol used in this study was selected for several reasons. Cycling, the most viable option, may not be an activity to which dancers are accustomed, and it is non-weightbearing; therefore, a treadmill protocol was selected. Both the Bruce and Balke protocols were developed to ascertain maximal oxygen consumption in relation to treadmill time, which can make them lengthy to conduct.[19] Recent studies have recommended individualized or modified incremental protocols, depending on the purpose of the test.[20] Although a common recommendation to elicit VO_2max values is that incremental treadmill work should last between 8 to12 minutes,[21] recent investigations of varying test durations ranging from 5 to 26 minutes have found no differences.[22-24]

The mean treadmill testing duration was almost 7 minutes (range: 4 to 8.5 minutes). HR_{peak}, VO_{2peak}, and RER_{peak} values were in the range of those reported for recreationally active and endurance trained athletes during maximal treadmill testing (HR_{max} = 177 to 188 beats·min^{-1}; VO_2max = 45.7 to 62.0 ml·kg^{-1}·min^{-1}; RER_{max} = 1.07 to1.17, respectively).[69-71] This suggests that our incremental treadmill test was a maximal test. HR_{peak} was 96% and 99% of age-predicted HR using both the 220-age and 211 - (0.64 * age) formulas.[72] Using the McArdle equation, the predicted VO_{2peak} for each of the step tests was quite robust when compared to the treadmill VO_{2peak}. The accuracy of the 112 step test HR_{recov} in predicting VO_{2peak} is an improvement over the 96 step test.

Previous studies have suggested that adult dancers demonstrate lower VO_2max values than other athletes. A review of oxygen uptake values in dancers indicates that female dancers typically exhibit a range of 40 to 55 and males 45 to 60 ml·kg^{-1}·min^{-1}. The greatest focus to date has been on assessing VO_2max in professional ballet dancers (females 39 to 53, males 46 to 59 ml·kg^{-1}·min^{-1}).[4,7,11,13] Less well studied are modern and other dance forms in professional or university level dancers. Relative VO_2max findings include professional modern (female only, 49),[47] professional jazz (female 42, male 49),[6] university ballet (female 41 to 47),[47] university modern (female 39 to 45, combined female and male, 51),[47,64,73] and professional competitive ballroom (female 42 to 54, male 53 to 61) dancers.[48,65,66] This study adds to current information on VO_2max in professional and university modern dancers, indicating that female modern dancers exhibit values similar to those of professional ballet and ballroom dancers, and male modern dancers exhibit higher values than their ballet and ballroom counterparts. Further study is necessary to confirm these findings; however, they are encouraging with regard to increased dancer fitness, suggesting that peak requirements of modern dancers can reach values of 60 to 65 ml·kg^{-1}·min^{-1}.[68]

Limitations

This study was conducted with trained professional and pre-professional dancers. They were a relatively homogeneous group, and their data may have resulted in lower correlations compared to a more heterogeneous sample. The inclusion of dancers from a wider level of training experience as well as dance styles is suggested in future study.

Although the accelerated step test was specifically devised for dancers, it does not employ dance-specific movements.

Repeatability of the step test was not studied here, as this has been well studied previously with high test-retest correlations (r = 0.92-0.94).[28,33,34,36,39,42]

We have chosen to report oxygen uptake in this study as VO_{2peak} rather than VO_2max. VO_{2peak} is the highest value of VO_2 attained on any given test, which does not necessarily reflect the highest value of which the subject being tested is capable. VO_{2peak} may occur without the characteristic plateau observed in VO_2max testing.[74]

Conclusion

It has been argued that because dance is a non-steady state activity, it is inappropriate to select steady state laboratory or field tests to determine dancer fitness.[75] However, performance demands today often require 25 minutes of continuous dancing, with some at vigorous levels of cardiorespiratory demand. This is particularly the case in modern dance, but it also encompasses other dance styles. Hence, sufficient aerobic fitness to recover quickly from bouts of intense dance movement is critical to enable optimal performance of subsequent choreographic sequences. Tests that afford a simple, quick assessment of fitness are warranted, and the accelerated 112 beats·min^{-1} step test explored in this study provides an efficient, acceptable tool for testing aerobic fitness in dancers.

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