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Validity of Using Heart Rate as a Predictor of Oxygen Consumption in Dance

Emma Redding, M.Sc., Matthew Wyon, Ph.D., Jeremy Shearman, Ph.D., and Lance Doggart, Ph.D.

Abstract

The validity of predicting oxygen uptake (VO_2) from heart rate (HR) was examined in 19 professional modern dancers of both genders ranging in age from 21 to 29 years. The subjects were measured on two occasions; once during a multi-stage graded treadmill test and again during their usual modern dance class. The data showed significant differences during both the treadmill test or dance class at lower intensities of less than 20 $ml \cdot kg^{-1} \cdot min^{-1}$ ($p \leq 0.03$) and paradoxically no significant differences between the relationships at intensities greater than 20 $ml \cdot kg^{-1} \cdot min^{-1}$. However results also identified large individual variability and when taken into account the great variability, it would seem unacceptable to predict the VO_2 from HR values in dance, based on the HR-VO_2 relationship established from a progressive treadmill protocol. Furthermore, given that dance is a non-steady-state activity and is executed at low to moderate intensities with occasional anaerobic bursts, it seems unlikely that the HR-VO_2 relationship established from a steady-state laboratory test can be relied upon as a predictor of VO_2 in dance.

An understanding of the energy requirements of dance can help in the development of more effective and appropriate training programs for dancers. However because of the intermittent and random movement pattern of dance, it has been difficult to accurately measure energy expenditure during the activity itself. Attempts at measuring the energy requirements of dance in previous studies have either involved the use of Douglas bag equipment[1,2] where movement restriction was noted or they have assumed oxygen uptake (VO_2) values from dance heart rates (HR) on the basis that the linear relationship between HR and VO_2[3,4] established in laboratory tests (treadmill or cycle ergometer) holds true for dance.[1,5] Dance is considered a non-steady-state activity[6,7] and, although the indirect method of predicting VO_2 from HR has been noted as reliable during steady-state activities,[3,8] the extent to which the relationship can be relied upon in non-steady-state conditions is questionable.[8-10]

The degree to which HR and VO_2 are related during activities that involve different muscle groups and changing work intensities is far from established. In 1995, Lothian and Farrally[11] found that heart rate gave a close estimate of VO_2 during intermittent exercise, while in 1996, Bernard and colleagues[8] suggested that the method can be depended upon during non-steady-state conditions providing that individual subject relationships are used. Dance can consist of fast jerky movements, off-balance turns, twists, and falls to the floor. Dance is multi-directional and involves the use and coordination of different muscle groups at varying times. No previous research has established the validity of this method of work rate prediction in dance. The aim of the current study was to investigate the validity of the use of HR in estimating VO_2 in dance from the HR-VO_2 relationship established in a steady-state laboratory test.

Methods

Nineteen professional dancers (n = 19; male 7, female 12) from two professional modern dance companies took part in the investigation (Table 1). Subjects completed the necessary consent and PAR-Q forms and were allowed time to become familiar with the equipment and protocols before the testing.

Initially, the dancers carried out the dance test, which was followed by the treadmill test. The dance test consisted of a technique class, which was familiar to the dancers. The class lasted 90 minutes and took place in the usual studio. The teachers were asked to conduct a normal class at

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Table 1 Subject Characteristics

Gender	Age (yr)	Height (cm)	Weight (kg)	BMI
Female (n = 12)	25 ± 4.0	166 ± 2.4	55.8 ± 1.3	20
Male (n = 7)	25 ± 4.4	173 ± 2.6	69.7 ± 2.0	23

an appropriate level to the dancers' abilities. Thirty minutes before the start of the class, the volunteer dancers were fitted with a heart rate monitor and the Cosmed K^4b^2 telemetric gas analyzer (Cosmed, Italy) so as to prevent interference with his or her warm-up routine and for the purposes of familiarization (Fig. 1). The dancer was told that the apparatus could be removed at any stage either to drink water or to terminate the test, however no subject asked for the equipment to be taken off during the tests. The class consisted of exercises that were typical of those normally performed at the advanced to professional level. The emphasis at the beginning of the class was on postural alignment, balance, and control. Movements were more static in nature compared with those during the second half of the class. The second half of the class consisted of more dynamic movement phrases that included more directional changes in space. Movements such as lunges and rolls to the floor, jumps, and springs were also executed.

On the same day, the dancers carried out a progressive graded test on a motor-driven treadmill using the same portable gas analyzer. The dancers expressed concern about running, as was the case in a previous study[12] and the treadmill protocol was modified

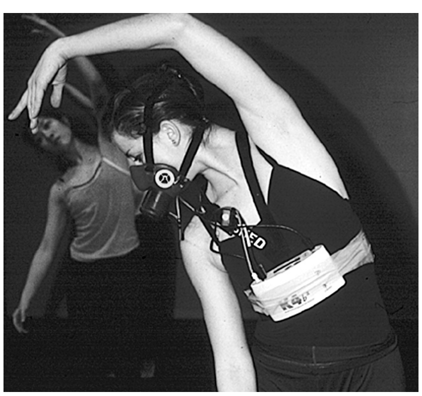

Figure 1 Dancer wearing the heart rate monitor and the Cosmed K^4b^2 telemetric gas analyzer (Cosmed, Italy).

as a result. There were six three-minute stages of a constant speed of 6.4 $km \cdot hr^{-1}$ and at each stage intensity was increased by a gradient increase of 3% starting at 0% (Table 2). The protocol was previously used by Mostardi and colleagues[12] with professional ballet dancers in 1983.

Statistical Analysis

Pearson's Product correlation test was used to assess the relationship between heart rate and oxygen consumption during dance and the progressive treadmill test for the whole group. A 2-way Analysis of Variance (ANOVA) was used to determine whether there was a significant difference between each stage for both protocols. Although mean differences are important (paired t-test), variation between individual scores must also be considered. In 2001, Atkinson and Nevill[13] suggested the use of limits of agreement (LOA), which take into account both the mean differences and the variability. The LOA calculation was used to determine the amount of agreement between HR in dance and HR in treadmill protocol at six arbitrary VO_2 settings (10, 20, 30, 40, 50, and 60 $ml \cdot kg^{-1} \cdot min^{-1}$).

Results

The correlation between heart rate and oxygen consumption during class was $r = 0.792$; $n = 2807$; $p < 0.001$ and during progressive treadmill work $r = 0.822$; $n = 1004$; $p < 0.001$. Figures 2 and 3 indicate the line of best fit

Table 2 Treadmill Protocol

Time (min)	Speed ($km \cdot hr^{-1}$)	Gradient (%)
0-3	6.4	0
3-6	6.4	3
6-9	6.4	6
9-12	6.4	9
12-15	6.4	12
15-18	6.4	15

for heart rate and oxygen consumption during class and treadmill work respectively.

The standard error of estimate for the prediction of oxygen consumption from heart rate data during dance was ± 5.904 $ml \cdot kg^{-1} \cdot min^{-1}$ and for treadmill work ± 8.437 $ml \cdot kg^{-1} \cdot min^{-1}$. The analysis of oxygen consumption at specific heart rates between class and treadmill work noted a number of significant differences. Significant differences were noted at 120 $b \cdot min^{-1}$($t = -2.046$; $df = 17$; $p = 0.05$), 130 $b \cdot min^{-1}$ ($t = -2.539$; $df = 17$; $p \leq 0.05$), 140 $b \cdot min^{-1}$($t = -2.833$; $df = 17$; $p \leq 0.01$) 150 $b \cdot min^{-1}$ ($t = -2.948$; $df = 17$; $p \leq 0.01$), 160 $b \cdot min^{-1}$ ($t = -2.744$; $df = 17$; $p \leq 0.01$), and 170 $b \cdot min^{-1}$ ($t = -2.909$; $df = 17$; $p \leq 0.01$).

The 2-way ANOVA and Tukey post-hoc analysis showed significant differences between all five HR stages and all five VO_2 stages for both protocols ($p < 0.05$). Table 3 shows the mean and standard deviation values for the subjects during both the class and treadmill protocols.

Table 5 shows the amount of agreement between HR values from the dance protocol with HR values from the treadmill protocol.

Results suggest that there could be at least 30 $b \cdot min^{-1}$ difference between the two protocols at any VO_2 value. At VO_2 10 $ml \cdot kg^{-1} \cdot min^{-1}$, the mean difference between the subjects for both protocols was 6 $b \cdot min^{-1}$. The standard deviation for the difference of these mean scores was ± 16.056 but the limits of agreement was 31.47 ($5.79 \times 1.96 = 31.47$). For a complete analysis, the mean difference is 5.79 ± 31.47 $b \cdot min^{-1}$. This suggests that for both protocols at VO_2 10 $ml \cdot kg^{-1} \cdot min^{-1}$, a subject's HR could potentially vary by up to 31 $b \cdot min^{-1}$. The agreement limit increases as intensity increases up to a variability of 49 $b \cdot min^{-1}$ at a VO_2 60 $ml \cdot kg^{-1} \cdot min^{-1}$.

Although there was no significant difference between the data sets, the level of agreement is unacceptable. For example, at VO_2 10 $ml \cdot kg^{-1} \cdot min^{-1}$, the mean difference between the two sets of data is approximately 5.79 $b \cdot min^{-1}$ with a SD of approximately 16 $b \cdot min^{-1}$

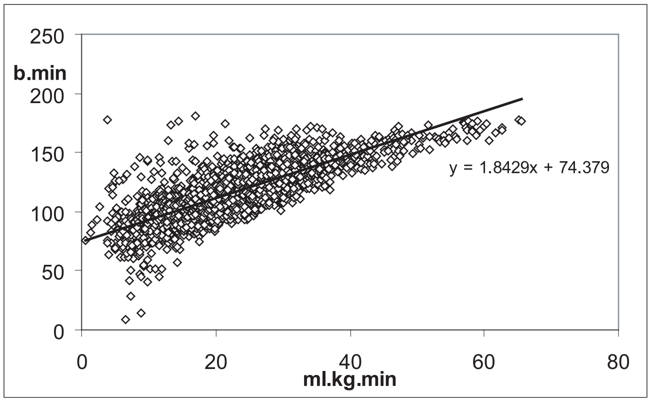

Figure 2 The HR-VO_2 relationship during dance protocol.

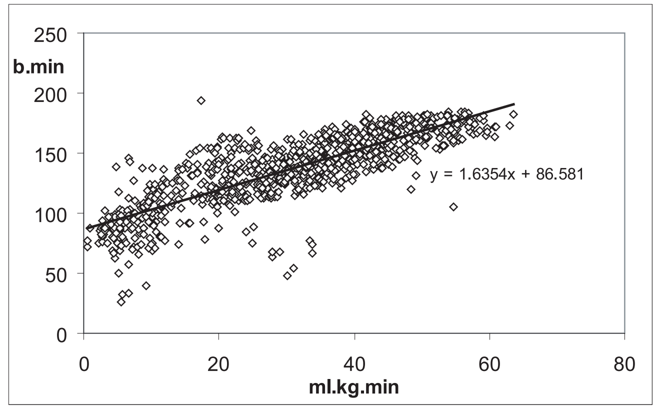

Figure 3 The HR-VO_2 relationship during progressive treadmill protocol.

suggesting that there is too much variability between the two protocols. In most cases, the HR values appear to be underestimated during the dancing.

Discussion

The aim of this study was to assess whether HR from dance (non-steady-state) could be used to predict VO_2 from data established in a lab test (steady state).

The results of the present study imply that the prediction of oxygen consumption from heart rates during dance is unreliable when a group-wise HR-VO_2 relationship during progressive exercise is used. Statistical analysis highlighted significant individual variances in the group data when examining the relationships of the predicted heart rates and arbitrarily given VO_2 values between dance and treadmill work. These findings support research by Bot and Hollander,[9] who recommended that individual regression lines should be used, rather than group-wise regression lines, during non-steady-state exercise. In other words, it may be possible to use HR values established during a treadmill protocol to predict VO_2 in dance only if individual data is obtained. This suggestion is also supported by previous studies.[8,11]

The present study assessed the HR-VO_2 relationships during two weight-bearing activities because such activity (treadmill running) is considered to produce a closer relationship than that found between weight-bearing (dance) and non-weight-bearing (i.e., cycle ergometer) activities. It appears however, that the extent to which work intensities change during an activity should also be considered when developing a lab protocol for dance. In other words, the lab protocol should more closely mimic the changing intermittent nature of dance. The findings of Bernard[8] would suggest that the steadier the state of an activity, in terms of its intensity, the greater the relationship between HR and VO_2 will be. It appears likely that the warm-up section of class may have a stronger HR-VO_2 relationship than the center

Table 3 Mean and Standard Deviation Values for the Subjects During Both the Class and Treadmill Protocols

Oxygen uptake (VO_2) ($ml \cdot kg^{-1} \cdot min^{-1}$)	Class mean HR ($b \cdot min^{-1}$)	Treadmill mean HR ($b \cdot min^{-1}$)
10	91.4 ± 9.9	97.2 ± 12.9
20	113.4 ± 8.8	117.8 ± 14.4
30	135.2 ± 10.9	138.5 ± 17.7
40	157.2 ± 15.0	159.1 ± 22.1
50	179.2 ± 19.8	179.8 ± 27.0
60	201.1 ± 25.0	200.4 ± 32.2

Table 4 Paired t test Differences Between Class and Treadmill Protocols at Varying Intensities

VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	t value	Significance
10	-1.57	0.13
20	-1.27	0.22
30	-0.86	0.40
40	-0.44	0.67
50	-0.11	0.91
60	0.13	0.89

Table 5 Limits of Agreement Between Class and Treadmill Protocol

VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	LOA	SD
10	5.79 ± 31.47	16.056
20	4.47 ± 30.17	15.395
30	3.2 ± 31.85	16.249
40	1.8 ± 36.1	18.421
50	0.6 ± 42.12	21.493
60	0.7 ± 49.33	25.166

section, which is more intermittent in nature.

The sensitivity of the dance-class-based protocol and the extent to which it is reflective of dance should be considered, bearing in mind that there are intricate movements in a dance class that may not be able to be performed using the gas analyzing equipment. Given that the lab protocol was over-estimating the data, it does not seem to be reflective of the dance class. It might be that the lab protocol was too dependent on gross movement, whereas the class incorporates intricate movement.

The physiological mechanisms attributed to the reliability of the HR-VO_2 relationship during steady-state versus non-steady-state exercise may relate to the changes in stroke volume during recovery immediately after exercise or sudden decrease in exercise intensity.[14] In order to maintain cardiac output, the heart rate remains high because of the decrease in stroke volume. Therefore the HR-VO_2 relationship during non-steady-state exercise cannot mimic the relationship in steady-state exercise as the oxygen consumption is reduced due to a decrease in exercise intensity while the HR remains high.

Future research efforts might re-examine this study using a non-steady-state lab protocol such as the Dance Aerobic Fitness Test (DAFT) developed by Wyon and Redding[15] so that the intermittent nature of dance is more closely mimicked. This idea was supported by Lothian and Farrally[11] who suggested that individual estimation of oxygen consumption was possible from heart rate data when a similar form of exercise was used to initially calculate the HR-VO_2 relationship.

Conclusion

It can be concluded that the use of steady-state treadmill running to generate a HR-VO_2 relationship for the prediction of oxygen consumption during dance is questionable and that the use of group-wise data may not be reliable.

Limitations

The main limitation with this study is the number of subjects used. Ideally a greater number would be required to examine this relationship more closely. As mentioned previously, it might be that the lab protocol used in this study was too steady state in nature to produce a close enough HR-VO_2 relationship for use in dancing which is more intermittent.

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