Development, Reliability, and Validity of a Multistage Dance Specific Aerobic Fitness Test (DAFT)

Matthew Wyon, M.Sc., C.S.C.S., Emma Redding, M.Sc., Grant Abt, Ph.D., Andrew Head, Ph.D., and N. Craig C. Sharp, Ph.D.

Abstract

The aim of this study was to design a multistage dance-specific aerobic field-test that would indicate whether a dancer had the cardiorespiratory capabilities to cope with the demands of dance class and performance. The test consisted of five progressively demanding dance sequences. The technical level of each stage was kept as simple as possible to reduce the effect of economy of movement so that the emphasis of the test was physiologically based rather than skill orientated. The reliability of the stage workloads was measured via oxygen uptake and heart rate using a telemetric gas analyzer. After an initial familiarization trial, subjects (n = 56: 24 males and 32 females) undertook the test twice within 48 hours. The results showed significant differences in oxygen requirement and heart rates between stages ($F [4, 172] = 803.522$; $p < 0.001$) and gender ($p < 0.01$). The $HR\text{-}VO_2$ relationship for the test was $r = 0.94$; $n = 3336$; $p < 0.001$ and the SEE was ± 4.506. Reliability of the DAFT was calculated by determining the coefficient of variation (CV) expressed as a percentage and the percentage change in the mean between trials (%Δmean). CV ranged between 1.4 and 6.0 and %Δmean between 0.2 and 6.3 for the stages. The use of dance specific moves and specific levels of the test equating to the mean oxygen demands of class and performance confirmed that logical validity had been achieved. Possible applications to the dance world are the monitoring of heart rate at each of the stages during the year; setting of a target stage attainment for an individual's readiness to undertake class or performance after injury and/or, setting specific aerobic capabilities for dancers post-holiday or for guest artists (below a specific mean heart rate during a designated stage).

There is a problem when administering a "maximal" test to dancers.[1] Dance is non-competitive and dancers do not need to strive against others during performance. Consequently, the intensity of the performance is set by the choreographer and the concept of "gritting your teeth" for the final push is not found within the environment of dance, probably due to the high skill factor required. Chatfield and colleagues[1] suggested that this has led to problems during physiological testing which require the participants to exert themselves maximally. Previous studies have reported that dancers' have achieved maximal oxygen uptake ranges of between 39 to 51 ml·kg·$^{-1}$min^{-1} for females and 48 to 59 ml·kg·$^{-1}$min^{-1} for males during laboratory tests.[1-10] Maximal exertion within a simplistic movement form (running or cycling) is alien to the dancer as the choreography during a performance generally determines maximal effort. Additionally, the result could be affected by the specificity of the tests used with regards to dance. Dancers experience mechanical problems when running and walking due to highly developed turn-out and limited dorsiflexion capabilities of the ankle, and physiotherapists often actively discourage running as an activity, though this has not been demonstrated scientifically.

Direct measurement of the physiological cost of dance has until now proven difficult due to the limitations of apparatus available to researchers. Schantz and Astrand[9] used Douglas bags as the method of gas collection but

Matthew Wyon, M.Sc., C.S.C.S., is in the School of Sport, Performing Arts and Leisure, University of Wolverhampton, Birmingham, England.

Grant Abt, Ph.D., is in the School of Sport and Outdoor Studies, St. Martin's College, Lancaster England.

Emma Redding, M.Sc., is at the Laban Centre, London, England.

Andrew Head, Ph.D., is in the School of Life and Sport Sciences, University of Roehampton Surrey, London, England.

N. Craig. C. Sharp, Ph.D., is in the Department of Sport Sciences, Brunel University, Isleworth, Middlesex, England.

Correspondence and reprint requests: Matthew A. Wyon, M.Sc., C.S.C.S., School of Sport, Performing Arts and Leisure, Walsal Campus, University of Wolverhampton, Gorway Road, Birmingham, England WS1 3EB.

noted problems with potential movement restriction (even in classical ballet) and the fact that the data provided were only a mean value of the workload. Other studies used heart rate monitors during dance, which overcame the problem of movement restriction.[2,6,8] The aforementioned studies indirectly calculated the oxygen requirement of dance by comparing the heart rates gained during class with those from a maximal oxygen uptake treadmill (or in some cases cycle) test. This method is also open to question as it assumes that the HR-VO_2 relationship during dance is the same as that for treadmill or cycle work. The results from Redding and colleague's[12] study indicated the flaw in this method, the HR-VO_2 relationship in dance and treadmill work produced predicted oxygen consumptions from heart rates that were significantly different. The movement patterns within dance are very diverse, ranging from multi-directional to the static holds. The physiological demands are considered to be high intensity, intermittent exercise in nature and to produce a HR-VO_2 relationship (r = 0.79,) less than that seen in steady state or incremental exercise (r = 0.82; r = 0.87 – 1.00).[11]

Oxygen uptake during performance and class ranges between 10 to 60 $ml{\cdot}kg^{-1}min^{-1}$ for both ballet[2,8,9,13,14] and contemporary dance.[15] The results from Wyon and associates[15] noted significant differences between the physiological demands of contemporary dance class and performance. The mean oxygen requirement of class for males and females was 22.06 ± 5.86 $ml{\cdot}kg^{-1}min^{-1}$ and 17.42 ± 2.75 respectively. While the mean requirements for performance were also low, they were significantly greater at 24.85 ± 5.83 $ml{\cdot}kg^{-1}min^{-1}$ and 23.34 ± 3.83 $ml{\cdot}kg^{-1}min^{-1}$ respectively. The main differences between class and performance were the periods spent at high intensities with performances requiring a significantly greater time (minutes) above 35 $ml{\cdot}kg^{-1}min^{-1}$ and 160 $b{\cdot}min^{-1}$ than class.

Aims

Field-testing allows those without access to laboratory equipment the ability to measure base fitness levels and training adaptations. However, the newness of dance science means that appropriate and specific field tests have not been developed. The aim of the present study was to produce a continuous incremental five-stage aerobic fitness test that used dance specific movements. The test was to have specific stages that corresponded to the mean oxygen requirement of dance class and dance performance. The movement sequence of each stage was designed so that both novice and elite dancers of the same gender would work at the same relative oxygen requirement. The test was designed to be able to observe changes in a dancer's aerobic fitness by their ability to dance at a higher stage or by recording lower heart rates during each stage during a repeat test thereby indicating an improvement in their aerobic power.

Method

Development of the Test

The development of the test proved to be difficult as the investigators wanted an initial dance sequence that could be elaborated on to gain the increased intensities required for the subsequent test stages. The aim was to add only one to two variations per test level so that the learning of the test was not a factor of its function. This was achieved by real-time reviewing of data from a telemetric gas analyzer and adapting the dance movements so that they fell within a 5 $ml{\cdot}kg^{-1}min^{-1}$ bandwidth.

The final test was designed around a 16-beat sequence. It was established that each stage should be 4 minutes in length and that the oxygen requirements of each stage would be within a 5 $ml{\cdot}kg^{-1}min^{-1}$ bandwidth. This enabled physiological steady state to be achieved even though the movement patterns that the dancer carried out were diverse. Intensity was increased at each stage either in terms of tempo, the size of movements or the inclusion of additional movements (Table 1). The movements were kept simple with regard to skill to allow novice and elite dancers to use the same test, thereby reducing the affect of movement economy. Dancers were eliminated from the test if: 1. They were behind the beat or, 2. Movements became compromised (e.g., arms and hands not held properly, feet not pointed). A telemetric gas analyzer (Cosmed K4 b^2, Italy) was used to measure oxygen consumption and heart rate during the test to allow reliability analysis.

Reliability, Validity, and HR-VO_2 Analysis

Fifty-six contemporary dancers (Table 2) undertook the test wearing the telemetric gas analyzer on two occasions, with not more than 48 hours between the tests. Each subject signed a consent form and PAR-Q and undertook a familiarization trial to learn the dance sequences 2 hours before starting the trial. Their skill level was also recorded as ei-

Table 1 Dance Aerobic Fitness Test

Stage	Tempo ($b{\cdot}min^{-1}$)	Movement
1	68	5 steps, lunge and recover. 4 sets of 2 pliés with 90° turn between each set. Repeat for 4 minutes.
2	78	5 steps, lunge and recover. 3 spring hops in a circle. 4 sets of 2 pliés with 90° turn between each set, arms moving between first and second position. Repeat for 4 minutes.
3	78	5 steps, lunge and recover. 3 spring hops in a circle include arm movements. 4 sets of hop plié with 90° turn between each set, arms moving between first and second position. Repeat for 4 minutes.
4	94	5 steps, lunge and recover. 3 spring hops in a circle include arm movements. 4 sets of hop, hop with 90° turn between each set, arms moving between first and second position. Repeat for 4 minutes.
5	108	5 springs, lunge and recover. 3 spring hops in a circle include arm movements. 4 sets of hop, hop with 90° turn between each set, arms moving between first and second position. Repeat for 4 minutes.

Table 2 Subject Data

Gender	Level	N	Years Dancing	Age (years)	Height (cm)	Weight (kg)
Female	Novice	13	1.4 ± 0.9	20 ± 1.2	1.63 ± 0.1	53.6 ± 4.6
	Elite	19	6.7 ± 2.3	23 ± 3.2	1.66 ± 0.1	51.2 ± 3.8
Male	Novice	8	1.1 ± 0.4	20 ± 2.8	1.75 ± 0.1	66.2 ± 7.2
	Elite	16	5.9 ± 3.1	24 ± 4.1	1.74 ± 0.2	67.9 ± 6.8

ther novice (presently in full-time training) or elite (graduate dance student or professional dancer). Mean relative oxygen uptake and heart rate were calculated for each stage. The HR-VO_2 data were plotted.

Statistical Analysis

A repeated measures ANOVA with within-subject repeated contrasts was used to analyze and detect a main effect for the relationship between the stages. To detect significant differences between gender and skill level for each individual stage, a factorial MANOVA was performed. Reliability of the test was calculated by determining the coefficient of variation (CV) and the percentage change in the mean between trials (%Δmean) as suggested by Hopkins and coworkers[16]; this is variation on the Bland-Altman test for reliability. The validity of the test was assessed logically.[17,18] The similarity between the mean oxygen requirements of dance class and performance and specific stages of the test was used for logical validity. Another aspect of logical validity was the termination criteria of the test. The moves chosen for the test were assessed as to their relevance to modern dancers. The "termination criteria" for the test were when pointed feet and arms in specific positions could not be maintained. Linear regression analysis was used to assess the HR-VO_2 relationship for the whole test and to calculate the standard error of the estimate.

Results

Test Stage Data

The oxygen consumption for each stage is depicted in Table 3. Repeated Measures ANOVA detected significant differences between the stages, ($F [4, 172] = 803.522$; $p < 0.001$). There was a significant difference between genders at each stage ($p < 0.01$) but no significant difference between skill levels was observed at each stage. Figure 1 provides an example of the test for a male and female subject.

Test Reliability

The variables measured were mean oxygen consumption ($ml \cdot kg^{-1} min^{-1}$) and heart rate ($b \cdot min^{-1}$) for each stage (Table 4). The acceptable percentage change in the coefficient of variation was set at 5% between the trials.

HR-VO_2 Relationship

Group-wise linear regression analysis noted that the HR-VO_2 relationship for the test was strong, $r = 0.91$; $n = 4462$; $p < 0.001$; and SEE ± 5.6 $b \cdot min^{-1}$ (Fig. 2).

Discussion

Hopkins and coworkers[16] suggested that one method of testing reliability was by analyzing the changes in the coefficient of variation between the trials, expressed as a percentage of change (a variation on the Bland-Altman method). They went on to note that the percentage changes below 5% between trials were considered to be reliable. As can be seen in Table 4, the percentage changes in the coefficient of variation for heart rates are all within this designated limit. The reliability for relative oxygen uptake is outside the 5% upper limit for stages 1 and 2, though it drops within the designated zone for the subsequent three stages. This may be due to the slow pace of the movement and the limited limb action seen in stages 1 and 2.

Validity for the test was assessed logically,[17,18] this refers to the concept that the test is valid by definition. The aim of the test was to be able determine whether a dancer could cope with the cardiorespiratory demands of class and performance. These criteria were met with stage 3 having a similar mean oxygen demand as a dance class (20 $ml \cdot kg^{-1} min^{-1}$).[2,9,15] Performance demands were more difficult to quantify, as the mean oxygen demand is very similar to that of class, though Wyon and associates[15] noted the work-to-rest ratio during performance indicated a greater reliance on the aerobic system to supply the energy demands of the high intensity dance periods than that seen in class that was more reliant on the ATP-CP system. The study by Wyon and associates also noted that not only were the dance periods longer during performance than class but were also at a higher oxygen demand (30 to 60 $ml \cdot kg^{-1} min^{-1}$). There were a number of reasons for limiting the test to an

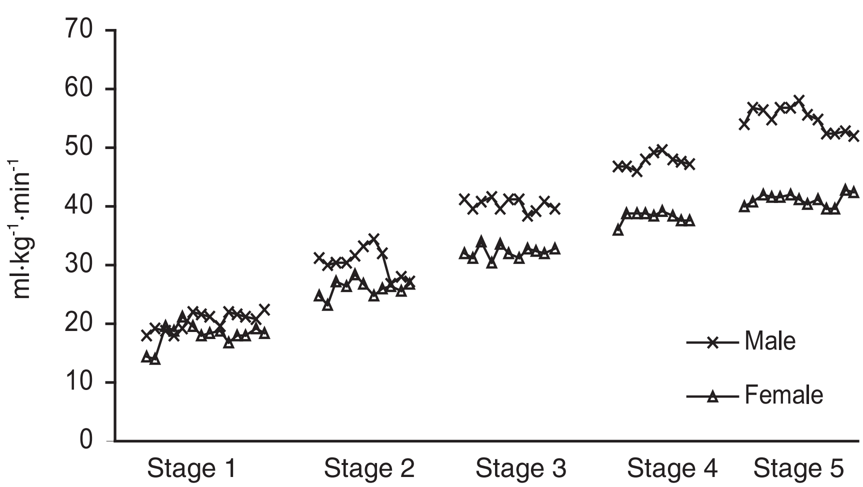

Figure 1 Representative oxygen uptake for a male and female dancer during the five stages of the test.

Table 3 Oxygen Uptake Requirements for Each Stage of the Test for Trials I and II

	Mean Relative Oxygen Uptake (ml·kg·$^{-1}$min^{-1}) Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Males					
Test I	21.7 ± 2.4	30.2 ± 3.7	39.7 ± 3.9	48.5 ± 3.6	55.7 ± 4.1
Test II	22.8 ± 2.4	32.2 ± 3.3	42.1 ± 2.5	50.3 ± 2.9	56.0 ± 3.5
Females					
Test I	19.7 ± 2.4	27.1 ± 3.6	34.1 ± 3.9	40.7 ± 4.4	46.0 ± 3.5
Test II	20.5 ± 2.3	28.1 ± 3.7	34.9 ± 3.8	41.6 ± 4.3	45.6 ± 4.5

Table 4 Stage Reliability

	Heart Rate CV (%)	%Δmean	Relative Oxygen Uptake CV (%)	%Δmean
Stage 1	2.7	0.2	5.5	6.3
Stage 2	3.5	1.3	6.0	6.2
Stage 3	2.6	3.3	3.5	5.1
Stage 4	1.7	1.6	1.4	3.3
Stage 5	1.5	0.6	3.6	0.7

oxygen uptake range of 46 ml·kg·$^{-1}$min^{-1} for female dancers and 55 ml·kg·$^{-1}$min^{-1} for male dancers. The maximal oxygen uptakes are within the ranges previously reported for dancers,[1-10] and although the peak oxygen requirements of dance performances are noted to exceed the oxygen requirements of the test,[9,13,15] the actual time the dancer is working at the higher intensity during a performance is very short. Moreover, there has been no research to date suggesting possible optimal VO_2max for dancers, perhaps due to the diverse nature of dance performance. It was decided by the authors that the oxygen requirement of the fifth stage of the test should be similar to that reported for maximal oxygen uptakes of other non-endurance sports.[19]

The HR-VO_2 relationship for the test ($r = 0.912$) was stronger than that seen during other dance activities (e.g., class and performance) ($r = 0.792$),[20] similar to that seen during progressive intensity exercise tests,[11,21] but less than seen in steady state exercise ($r = 0.95$ to 0.99).[22,23] Possible reasons for this could be due to the length of time at each stage (4 minutes) and the small fluctuation in workload during each stage (5 ml·kg·$^{-1}$min^{-1}). The low standard error of estimate (± 5.6 ml·kg·$^{-1}$min^{-1}) and the high correlation between heart rate and oxygen consumption allow for reasonably accurate prediction of oxygen consumption from heart rate data; thereby increasing the efficacy of the test as a field method for monitoring work intensities and changes in aerobic fitness levels. This was demonstrated by Redding and Wyon[24] who monitored two dance companies over a period of time comparing physiological adaptation from class and performance.

The stages increase by approximately 7 ml·kg·$^{-1}$min^{-1} for females and 8 ml·kg·$^{-1}$min^{-1} for males, providing clear separation of each stage. The aim of the study was to devise a test that measured aerobic fitness rather than skill, and this was achieved as there were no significant differences observed between novice and elite dancers in any of the stages. The decision to emphasize physiological parameters rather than skill was due to the fact that dance training tends to emphasize skill and technique, perhaps to the detriment of the relevant physiological parameters of fitness. One of the main reported causes of injury within the dance world is a reduced level of physical fitness.[10,25,26] A test of this type will help provide reliable and relevant information regarding the aerobic fitness levels of dancers, which may thereby help reduce injury risk.

The use of submaximal aerobic fitness tests to predict maximal oxygen uptakes must be viewed with caution. At high relative workloads, the HR-VO_2 relationship changes from the linear seen at submaximal intensities; therefore the use of linear regression to calculate VO_2 max by plotting submaximal heart rates against known workloads will cause an over prediction of the value. This was the reason that the test was designed so that two stages had similar oxygen requirements as that seen for the two main aspects of dance – performance and class.

There are a number of possible applications of the test to the dance

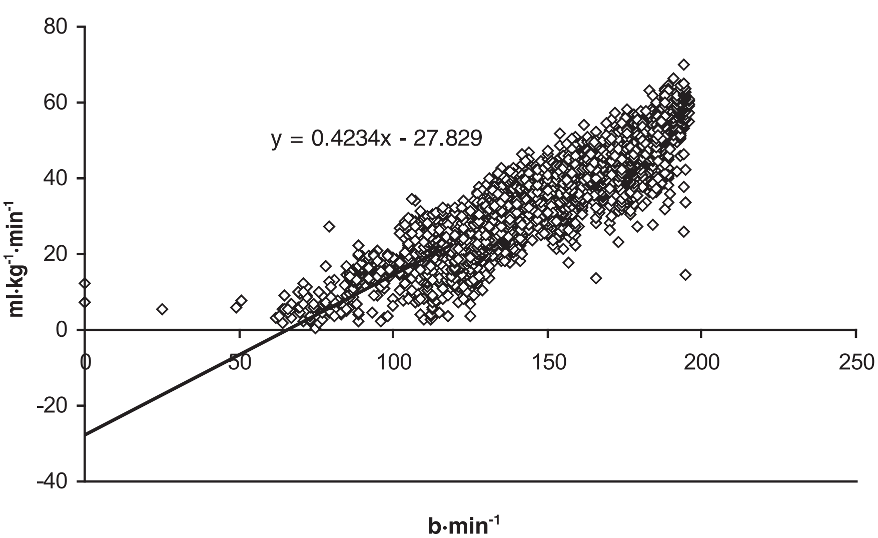

Figure 2 HR-VO_2 relationship for the test.

world. These could include setting specific stage targets to be met at the start of training and at the commencement of rehearsals or performances. The specific targets would need to be set by artistic directors, physiotherapists, teachers, or choreographers. For example, the mean oxygen requirement for dance class is 17 ml·kg·$^{-1}$min^{-1} for females and 21 ml·kg·$^{-1}$min^{-1} for males and approximately 85% of the class are below the oxygen requirement of stage three (34 ml·kg·$^{-1}$min^{-1} and 39 ml·kg·$^{-1}$min^{-1}, respectively). Therefore a pre-requisite for dancers returning from holiday might be to reach level three, which would imply that they had the physiological capability to cope with class. Due to the simplistic nature of the dance movements during the test, it is ideal in determining whether a dancer is physiologically ready to return to class or performing after injury without the added complication of skill. The use of the test to predict maximal oxygen uptake has been highlighted, but further research is needed to examine this ability.

Limitations

The main limitation for the study is the low number of subjects. This is very apparent for the issue of validity. The other limitations are concerned with the administration of the test; presently its designers have only taught the test to subjects and possible differences in the physiological parameters have not been monitored when others teach the movements to subjects. The effects of learning the sequences from video and the use of the subjective test termination criteria have not been examined and further research is needed to examine whether the error is increased.

Conclusion

The test has shown to be a reliable and valid field test capable of measuring a dancer's physiological ability to cope with the aerobic demands of class and performance. The null hypotheses that stated there would be no significant difference between stages for mean oxygen consumption and heart rate; between genders for mean oxygen consumption for each stage; or in oxygen consumption between dancers' ability levels can be rejected.

References

1. Chatfield SJ, et al: Cross-sectional physiologic profiling of modern dancers. Dance Research Journal 22(1):13-20, 1990.
2. Cohen JL, et al: Cardiorespiratory responses to ballet exercise and VO2max of elite ballet dancers. Med Sci Sport Exerc 14(3):212-217, 1982.
3. Dahlstrom M, et al: Physical fitness and physical effort in dancers: A comparison of four major dance styles. Impulse 4:193-209, 1996.
4. Chmelar RD, et al: A physiologic profile comparing levels and styles of female dancers. Physician Sportsmed 16(7):87-94, 1988.
5. Mostardi RA, et al: Musculoskeletal and cardiopulmonary characteristics of the professional ballet dancer. Physician Sportsmed 11(12): 53-61, 1983.
6. Novak LP, Magill LA, Schutte JE: Maximal oxygen intake and body composition of female dancers. Eur J Applied Physiol 39:227-282, 1978.
7. Padfield JA, et al: Physiological profiles of performing and recreational early adolescent female dancers. Pediatr Exerc Sci 5:51-59, 1993.
8. Rimmer JH, Jay D, Plowman SA: Physiological characteristics of trained dancers and intensity level of ballet class and rehearsal. Impulse 2:97-105, 1994.
9. Schantz PG, Astrand PO: Physiological characteristics of classical ballet. Med Sci Sport Exerc 16(5):472-476, 1984.
10. Brinson P, Dick F: *Fit to Dance?* London: Calouste Gulbenkian Foundation, 1996,
11. Bernard T, et al: Relationships between oxygen consumption and heart rate in transitory and steady states of exercise and during recovery: Influence of type of exercise. Eur J Appl Physiol 75:170-176, 1997.
12. Redding E, Wyon MA, Sellens MH, Shearman JP: Heart rate and oxygen kinetics in contemporary dance: Development of a submaximal aerobic test of dance performance. Presented at the Tenth Annual Meeting of the International Association for Dance Medicine and Science, Miami, Florida, 2000.
13. Cohen JL, Segal KR, McArdle WD: Heart rate response to ballet stage performance. Physician Sportsmed 10(11):120-133, 1982.
14. Kirkendall DT, Calabrese LH: Physiological aspects of dance. Clin Sports Med 2(3):525-537, 1983.
15. Wyon M, Abt G, Redding E, Head A, Sharp NC: Oxygen uptake during modern dance class, rehearsal and performance. J Strength Conditioning (in press).
16. Hopkins W, Schabort E, Hawley J: Reliability of power in physical performance tests. Sports Med 31(3):211-234, 2001.
17. Thomas J, Nelson J: *Research Methods in Physical Activity*. Champaign, IL: Human Kinetics Publishers, Inc., 1996, pp. 214-215.
18. Vincent W: *Statistics in Kinesiology*. Champaign, IL: Human Kinetics Publishers, Inc., 1999, pp. 2-3.
19. Gore C: *Physiological Tests for Elite Athletes*. Champaign, IL: Human Kinetics Publishers, Inc., 2000.
20. Wyon MA: The cardiorespiratory demands of contemporary dance [thesis]. University of Roehampton, Surrey, 2003.
21. Matthys D, et al: Cardiorespiratory variables during a continuous ramp exercise protocol in young adults. Acta Cardiologica 51:451-459, 1996.
22. Londeree B, Ames S: Trend analysis of the %VO2max - HR regression. Med Sci Sport Exerc 8:122-125, 1976.
23. Londeree B, et al: %VO2max versus %HRmax regressions for 6 modes of exercise. Med Sci Sport Exerc 27:458-461, 1995.
24. Redding E, Wyon M: A comparative analysis of the physiological responses to training before and at the end of a performing period of two dance companies. Presented at the Eleventh Annual Meeting of the International Association for Dance Medicine and Science. Madrid, Spain, 2001.
25. Koutedakis Y, et al: The effects of rest and subsequent training on selected physiological parameters in professional female classical dancers. Intl J Sports Med 20(6):379-383, 1999.
26. Koutedakis Y, Agrawal A, Sharp NCC: Isokinetic characteristics of knee flexors and extensors in male dancers, Olympic oarsmen, Olympic bobsleighers, and non-athletes. J Dance Med Sci 2(2):63-67, 1999.