Cardiorespiratory Training for Dancers

Article *in* Journal of dance medicine & science: official publication of the International Association for Dance Medicine & Science · January 2005

1 author:

Matthew Wyon
University of Wolverhampton

Cardiorespiratory Training for Dancers

Matthew Wyon, Ph.D.

Abstract

Dance performance has been classified as high-intensity intermittent exercise that utilizes the aerobic and glycolytic energy production systems. Dance class and rehearsal have been shown to inadequately stress these energy systems and supplemental training is one method of preparing the body to meet these demands. The use of interval exercise training to elicit the required training effect has been suggested and the recommended exercise-to-rest ratios are examined in relation to the underlying physiology. The training environment and frequency is also examined with regard to movement specificity and the need for peripheral adaptations to occur in appropriate muscle fibers. Finally, the levels of dancers (professional, vocational student, and recreational) are discussed in relation to the importance of supplemental training to their goals.

Dance is a high skill exercise format, similar to rhythmic gymnastics, where physical prowess is seen as solely a foundation to the demonstration of complex skill sequences. Though there are a number of different genres within dance, there is little physiological difference between its two main forms, classical ballet and contemporary dance.[1-4] Both have a basic skill acquisition or perfecting environment (dance class), a performance preparation period (rehearsal), and stage performance period. The basic format of dance class contains elements such as warm-up (which is at a lower physiological intensity and is more continuous in nature) and center work (which is characterized by short high-intensity periods with long rest periods).[2] Little research has examined the physiological demands of rehearsal mainly due to the invasive nature of data collection on the artistic process. The data that is available highlights the diversity in the physical stresses during the rehearsal process.[5,6] Early rehearsals were observed to have a mean heart rate below 110 $b \cdot min^{-1}$, while later rehearsals had a similar demand of the subsequent performance pieces. Performance demands vary considerably and the absolute physiological workload is dependent on the choreography, while the relative intensity is associated with the physical fitness of the dancer.[7] However, some general observations can be made. A number of studies have reported an increased demand placed on the fast glycolytic and aerobic systems during dance performance over that noted in dance class.[5,8,9] This is mainly due to the dance sequences being longer and with less rest between sequences.[6]

Matthew Wyon, Ph.D., is in the Department of Sport, Performing Arts and Leisure, University of Wolverhampton, West Midlands, England.

Correspondence: Matthew Wyon, Ph.D., School of Sport, Performing Arts and Leisure, Walsall Campus, University of Wolverhampton, Gorway Road, Walsall WS1 3EB, England.

Dance and the Energy Systems

The utilization of exercise physiology studies that examine the limitations of energy supply[10] becomes more complex when examining the underlying physiological demands of dance due to the high skill element integral to this form of exercise. Data on dancers' fitness revealed that none of their energy systems have been overly developed.[3-5,11-15] Dancers perceive "fitness" as an important aspect of performance but there has been a lack of empirical evidence that demonstrates the relationship between the development of specific energy systems and improvements in dance performance.[16]

Dance has been classified as high-intensity intermittent exercise.[3,5,6,17] The energy systems utilized during the periods of activity are dependent on a number of variables: the intensity of the activity itself, the duration of the activity, and the period of rest between the activity periods.[18,19] A closer examination of dance indicates a number of distinct areas that have different metabolic demands.

Dance class has two distinct sections, the warm-up and the center. The warm-up section is characterized by moderate-duration (4 to 5 minutes

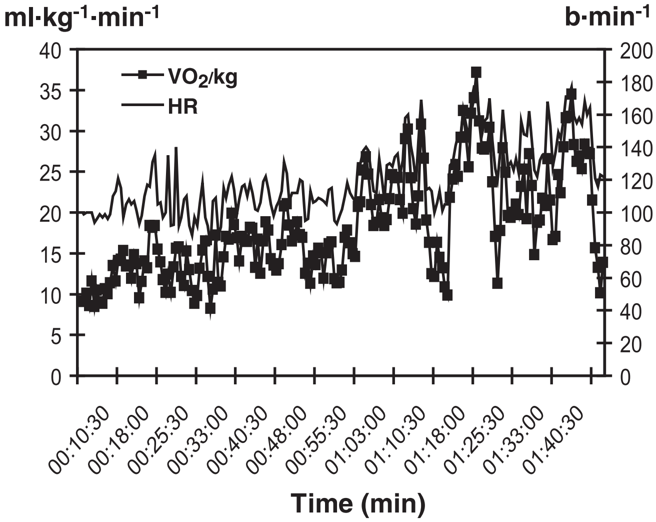

Figure 1 An example of heart rate and oxygen consumption during a dance class.

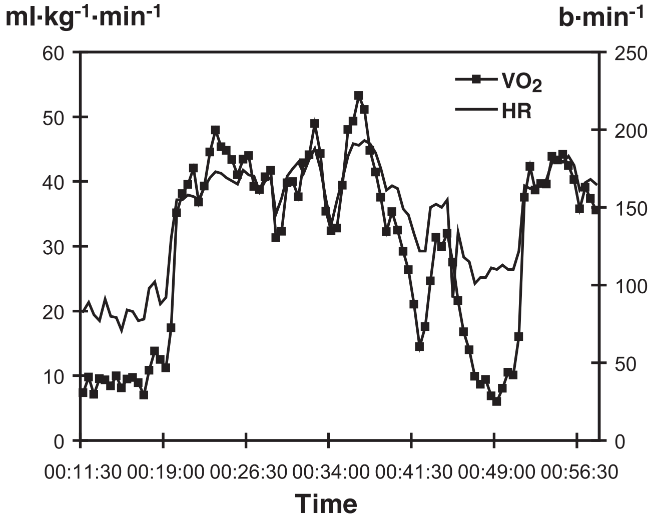

Figure 2 An example of the physiological demands of performance.

or more) low-intensity exercise periods (mean heart rates between 117 to 134 b·min^{-1}),[2,4] which suggests that the aerobic system is capable of meeting the muscular energy demands. The center section of class is characterized by periods of intense activity lasting 10 to 40 seconds interspersed between longer periods of rest (2 to 5 minutes) (Fig.1). Research suggests that in these circumstances all the energy systems are being utilized to meet the muscular demands for adenosine triphosphate (ATP), though short-term high-intensity exercise is often referred to as anaerobic exercise.[20-23] The long recovery periods allow full recovery of each system even though the exercise is in repetitive bouts.[24,25]

Data on dance performance suggest that the intensity of performance is often similar to that seen during the center phase of dance class,[3,4,9] although the duration of exercise is normally longer (1 to 4 minutes). This, accompanied by the increased levels of lactate (11 mmol·L^{-1}),[3] suggests that the muscular energy demands are being met by the lactate and aerobic systems (Fig. 2). The differences in energy system utilization during the rehearsal and performance period was highlighted by Wyon and colleagues.[7] In their study there was no change in aerobic fitness during the rehearsal period, but a significant increase during the performance period. This emphasizes the variation in energy system utilization during the different aspects of the dancer's training.

Energy System Utilization

For physical work to occur, whether performance or training, production of sufficient energy is a prerequisite. Through a complex series of biochemical conversions, adenosine triphosphate (ATP) is ultimately derived from the foodstuffs that are ingested and is constantly restored within cells. As there are limited stores of ATP within cells (approximately 25 mmol of ATP per kilogram of dry muscle[26]), ATP needs to be continually regenerated during physical activity. The availability of oxygen at the cellular level determines which pathway of two possibilities actually occurs; the rate of demand for ATP by the cell also has a major influence on the energy systems that are used. Generally ATP is developed aerobically (oxidatively) via the mitochondria, but as the rate of energy demand increases this system becomes increasingly inadequate as a means to provide the ATP. To help meet these demands, the anaerobic system (glycogenolysis) produces ever-increasing quantities of ATP. For sudden bursts of increased work-rate the muscle cell has limited stores of ATP and creatine phosphate (CP) that can provide energy for 5 to 10 seconds of maximal work.

The different systems of ATP production should be viewed as a continuum from high-energy phosphates supplying the energy at one end (very short duration) to energy being provided aerobically (prolonged duration) at the other. At any one time all energy systems are in use but the percentage use of each energy system is determined by the rate of demand for ATP by the muscle cell. For instance, during a 6-second maximal sprint the glycolytic contribution is estimated to be 49%; at 30-seconds the aerobic contribution is approximately 16%, the glycolytic 56%, and the ATP-CP 28%. As the exercise period increases, the percentage of energy derived from anaerobic metabolism decreases since the aerobic system provides more. At two minutes maximal exercise, the aerobic and anaerobic energy production systems are each producing approximately 50% of the total ATP requirement.[7,27] Steady-state maximal exercise lasting more than 4 minutes sees the aerobic system largely dominating in the provision of energy. It must also be remembered that the velocity at which an individual can run will decrease as the time and the reliance on the aerobic system increase.

The beneficial role of training the aerobic system has long been emphasized[28,29]; a well-developed aerobic system increases total energy available even during events that are predominantly anaerobic. A high aerobic capacity is beneficial to a performer in an anaerobic event as it will aid a faster recovery between bouts of high-intensity exercise and provide a greater amount of ATP via aerobic glycolysis.

Energy Systems of Repetitive High-Intensity Exercise

The energy required for one bout of high-intensity exercise is provided through anaerobic pathways (creatine phosphate and glycogenolysis).[30] When the exercise comprises repetitive bouts of brief high-intensity (maximal) exercise, the relative contributions to ATP resynthesis need to be reassessed. The limitation of each system is the speed at which it can reach homeostasis after being depleted. Full restoration of glycogen can be a long process and is dependent on the type of exercise that was undertaken. The rate of glycogen resynthesis after prolonged exercise is much slower than that observed after high-intensity, short-duration exercise.[31,32] Pascoe and Gladden[33] noted that 70% of phosphagen restoration occurred in 30 seconds and full restoration took 3 to 5 minutes. Factors that can influence CP restoration are the concentrations of ATP, adenosine diphosphate (ADP), and creatine (Cr) within the cell. Another major factor is the concentration of H^+; a low cell pH will inhibit creatine kinase thereby impairing the resynthesis of CP.

A number of factors could influence the increased glycogen resynthesis rates seen after high-intensity short-duration exercise. They include muscle fiber utilization, the glycolytic intermediates, the use of lactate in glyconeogenesis, and the affects of blood glucose and insulin.

Generally during high-intensity exercise the fast twitch (Type II) fibers are recruited. These have a greater glycolytic ability than Type I fibers and therefore it has been suggested that there is a greater breakdown of glycogen in these fibers during high-intensity exercise.[34] After high-intensity short-duration exercise, there are reduced levels of muscle glycogen and elevated levels of glycolytic intermediates. The elevation of glucose-6-phosphate (intermediate) to levels twelve-fold in concentration[35] is important in the resynthesis, not only as a substrate but also as an activator of glycogen synthase. The elevated concentrations of glucose and glycolytic intermediates could account for up to 45% of the resynthesis potential immediately after exercise.[33] High-intensity intermittent exercise has a restoration period of between 2 hours for partial restoration and up to 24 hours for full restoration.[31] If the exercise was of a continuous, high-intensity nature, then the recovery can take up to 48 hours.

Initial research suggested that limited periods of recovery (30 seconds) would see a reduction of CP content of the muscles with a greater emphasis on glycogenolysis to anaerobically produce ATP in the subsequent bout.[36] Repetitive sprints (ten 6-second sprints with 30 second rest periods) showed that the first sprint was mainly generated by energy derived from CP and anaerobic glycogenolysis.[37] The final sprint saw no increase in lactate levels, yet the mean power output had decreased by 73%. Before the last sprint, CP stores were at 43% of initial stores and fell to 16% at the end of the sprint. The CP stores probably accounted for 90% of ATP production; this suggests that a 30-second recovery phase is enough to allow sufficient replenishment of the CP stores to cope with maximal-intensity short-duration exercise.

Increasing the rest period to 60-second showed significantly higher mean power outputs though there was no difference between the 30 and 60 second rest periods when peak power was analyzed.[38] This was put down to greater regeneration of CP stores and more time for translocation of H^+ ions out of the muscle cell.

Training for High-Intensity Intermittent Exercise

Due to the physiological variation in performances there is no magic answer to optimal cardiorespiratory preparation. I suggest the development of the aerobic and fast glycolytic systems initially and as the rehearsal period intensifies toward performance, then the specificity of cardiorespiratory development is met within the actual rehearsal process. Ideally this would be in a periodized training program that takes into account total training load from all training formats – class, rehearsal, and supplemental training.[39] The development of these systems ideally needs to be within a three-tier process; the first stage develops an aerobic foundation, the second stage facilitates maximal aerobic power, and the third stage develops the fast glycolytic system.

Aerobic Foundation

This is a vital aspect to all training programs as it exposes the body to continuous moderate intensity exercise for a prolonged period of time[18,40] that promotes general conditioning for the dancer. The format of the training can either be specific (dance movements) or general (circuit training),[41] but the intensity needs to be between 60% to 85% of an individual's maximal aerobic power (VO_2max), 70% to 90% HRmax or 14 to 17 rate of perceived exertion (RPE)[42] continuously. The duration of the training sessions should between 20 to 40 minutes; I suggest that as long as the intensity is maintained within the session, then its duration can be toward the lower end. On a note of caution, the overdevelopment of aerobic endurance can have a negative effect on the body's ability to produce ATP anaerobically since concentrations of specific anaerobic enzymes are suppressed.[10,43]

Aerobic Power

According to Bangso[44,45] the development of VO_2max is important in the recovery between high-intensity bouts. Research suggests that this is best achieved by interval training[46-48] as more work can be performed at higher intensities with the same or less fatigue compared to continuous training. By increasing a dancer's VO_2max it allows them to carry out the same exercise at a lower relative workload thereby delaying the effect of fatigue, which is a major perceived cause of injury within dance.[13] The exercise to rest ratio is 1:1, with the optimum exercise time for each bout being between 3 to 6 minutes.[46] The intensity of each bout needs to be near maximum, in that at the end of each bout the RPE is 16 to 17. The workload should respond to 90% to 95% of VO_2max or 90% to 95% of HRmax. The rest periods are not actual rest periods but periods of low-intensity exercise as this promotes faster recovery of the exercise bouts.[49]

The Fast Glycolytic System

This type of training is not truly anaerobic as even in a supramaximal single-bout 30-second exercise period (Wingate test) the aerobic system provides nearly 50% of the total energy demand.[50] Interval training is often the suggested mode, though some investigators prefer to refer it as repeated sprint training.[51] The suggested exercise-to-rest ratio for this type of exercise is 1:3 to 1:5 with a typical exercise time being 15 to 30 seconds. The exercise intensity is often classified as supramaximal as it is beyond the intensity seen at VO_2max; studies have reported using intensities of 170% to 200%,[25] which corresponds to an RPE of 18 to 19. Again the rest periods are active to promote recovery.

Training Mode

The conditioning classes could, and ideally should, utilize dance movements to elicit a training effect by lengthening the dance periods during center work and reducing the rest time. The emphasis would need to be on training effect rather than movement accuracy or otherwise the training benefits would be lost. The importance of movement specificity is with regard to peripheral adaptations to the different types of cardiorespiratory training.[52] Any type of training, as long as it follows the "rules" mentioned above, can generate central adaptations, but movement specificity will allow peripheral adaptations to occur in the muscles (actually the muscle fibers) that are used within dance. This is especially important in the development of the anaerobic systems where little adaptation is seen centrally.[10]

Training Frequency

The addition of supplemental training, to what most perceive as an already hectic schedule, needs to be done with care as otherwise it would possibly increase the injury rate and occurrence of overtraining.[53] One method, for professionals, would be the substitution of one or two dance classes a week with physical conditioning as this would have a beneficial affect on the dancers underlying physical fitness without interfering or causing a deterioration of skill. There should be enough skill reinforcement within three classes a week, rehearsals, and performances to maintain skill levels – though this has not been examined. Another method is to set a number of sessions to be fitted into the dancer's schedule, and it is up to her discretion when to fit them in. Ideally three to four sessions should be undertaken a week if improvements in the targeted energy system are required,[54] but the precise frequency remains elusive.[55,56] In periods of intense rehearsal or performance, a maintenance program can be implemented that only requires one to two sessions per week.

For dancers at vocational dance schools, although they are aiming to become professionals, the goal of their training is slightly different and therefore this has an effect on supplementary training requirements. The difference between professionals and students is that the main goal of professionals is performance while for students it is technique perfection. Research has suggested that fatigue has the greatest effect on technique and injury occurrence[13] and therefore the emphasis of their supplemental training should be aerobic conditioning. Due to dance students' hectic schedules, supplemental sessions should be kept to a minimum if not incorporated into dance sessions; I suggest one to two a week.

For recreational dancers (taking class one to three times per week) the emphasis needs to be on the enjoyment of dancing rather than actual specific physiological conditioning. These dancers should follow the guidelines set out by the American College of Sports Medicine[57] for health maintenance.

Conclusion

Dance is a skill-based art form. However, unless the "physiological dancer" is honed to the same extent as the "artistic dancer," the limiting factor within their performance capabilities will potentially be their physical conditioning. Research studies have indicated the benefits of supplemental exercise training, including increased strength and active flexibility. The integration of these sessions must be carefully introduced into dancers' schedules and there may be a need for these sessions to take the place of some dance classes to prevent overtraining. The way a dancer is trained, especially within a company environment, should be reviewed.

References

1. Dahlstrom M, et al: Physical fitness and physical effort in dancers: a comparison of four major dance styles. Impulse 4:193-209, 1996.
2. Wyon M, et al: The cardiorespiratory responses to modern dance classes: Differences between university, graduate, and professional classes. J Dance Med Sci 6(2):41-45, 2002.
3. Schantz PG, Astrand PO: Physiological characteristics of classical ballet. Med Sci Sport and Exerc 16(5):472-476, 1984.
4. Cohen JL, et al: Cardiorespiratory responses to ballet exercise and VO2max of elite ballet dancers. Med Sci Sport Exerc 14(3):212-217, 1982.
5. Rimmer JH, Jay D, Plowman SA: Physiological characteristics of trained dancers and intensity level of ballet class and rehearsal. Impulse 2:97-105, 1994.
6. Wyon M: *Cardiorespiratory Demands of Contemporary Dance, in School of Life and Sport Sciences*. University of Roehampton Surrey: London, 2004.
7. Wyon MA Redding E: The physiological monitoring of cardiorespira-

tory adaptations during rehearsal and performance of contemporary dance. Journal of Strength and Conditioning Research (In press).
8. Wyon MA, et al: Oxygen uptake during of modern dance class, rehearsal and performance. Journal of Strength and Conditioning Research 18(3):646-649, 2004.
9. Cohen JL, Segal KR, McArdle WD: Heart rate response to ballet stage performance. Phys Sportsmed 10(11):120-133, 1982.
10. Maughan R, Gleeson M, Greenhaff PL: *Biochemistry of Exercise and Training*. Oxford: Oxford University Press, 1997.
11. Chatfield SJ, et al: Cross-sectional physiologic profiling of modern dancers. Dance Research Journal 22(1):13-20, 1990.
12. Koutedakis Y, Sharp NCC: *The Fit and Healthy Dancer*. Chichester, England: John Wiley and Sons, 1999.
13. Brinson P, Dick F: *Fit to Dance*? London: Calouste Gulbenkian Foundation, 1996.
14. Padfield JA, et al: Physiological profiles of performing and recreational early adolescent female dancers. Pediatric Exercise Science 5:51-59, 1993.
15. Redding E, Wyon MA: Strengths and weaknesses of current methods for evaluating the aerobic power of dancers. J Dance Med Sci 7(1):10-16, 2003.
16. Wyon M, Wyon C, Redding E: Qualitative examination of the physiological attributes required for contemporary dance. *In: International Association of Dance Medicine and Science XI Encuentro Anual*. Alcala de Henares, Spain: International Association of Dance Medicine and Science, 2001.
17. Cohen A: Dance: aerobic and anaerobic. Journal of Physical Education, Recreation and Dance, March, pp. 51-53, 1984.
18. Bompa TO: *Theory and Methodology of Training: The Key to Athletic Performance* (3rd ed). Dubuque, Iowa: Kendall/Hunt, 1994.
19. Bangsbo J: Physiology of training in science and soccer. *In:* Reilly T (ed): *Science and Football III*. London: E&FN SPON, 1996, pp. 51-64.
20. Boobis LH: Metabolic aspects of fatigue during sprinting. *In:* Macleod D, et al (eds): *Exercise: Benefits, Limits and Adaptations*. London: E&FN Spon, 1987, pp. 116-143.
21. Gastin PB: Energy system interaction and relative contribution during maximal exercise. Sports Med 31(10):725-741, 2001.
22. Gaitanos GC, et al: Human muscle metabolism during intermittent maximal exercise. J Appl Physiol 75(2):712-719, 1993.
23. Hill DW, Smith JC: Calculation of aerobic contribution during high-intensity exercise. Res Q Exerc Sport 63(1):85-88, 1991.
24. Bogdanis GC, et al: Recovery of power output and muscle metabolites following 30 s of maximal sprint cycling in man. J Physiol 482:467-480, 1995.
25. Tabata I, et al: Metabolic profile of high-intensity intermittent exercises. Med Science Sport and Exerc 29(3):390-395, 1997.
26. Hultman E, Sjoholm H: Substrate availability. *In:* Knuttgen HG, Vogel JA, Poortman J (eds): *Biochemistry of Exercise*. Champaign, IL: Human Kinetics Publishers, Inc., 1983, pp. 63-75.
27. McArdle WD, Katch VL, Katch FI: *Exercise Physiology: Energy, Nutrition and Human Performance*. Baltimore: Williams and Wilkins, 1996.
28. MacDougall JD, et al: Muscle glycogen repletion after high-intensity intermittent exercise. J Appl Physiol 42:129-132, 1977.
29. Mader A, Bompa T: Developing and monitoring endurance of elite athletes. *In: Developing and Monitoring Endurance of Elite Athletes*. Toronto: Canadian Olympic Association and Coaching Association of Canada, 1986.
30. Jacobs I, et al: Lactate in human skeletal muscle after 10 and 30 s of supramaximal exercise. J Appl Physiol 55(2):365-367,1983.
31. Bangsbo J, Saltin B: Recovery of muscle from exercise: its importance for subsequent performance. *In:* Macleod M, et al (eds): *Intermittent High-Intensity Exercise: Preparation, Stresses and Damage Limitations*. London: E &FN Spon, 1993, pp. 49-69.
32. Blom P, Vollestad NK, Costill DL: Factors affecting changes in muscle glycogen concentration during and after prolonged exercise. Acta Physiol Scand 125(Suppl):67-74, 1986.
33. Pascoe DD, Gladden LB: Muscle glycogen resynthesis after short-term, high-intensity exercise and resistance exercise. Sports Med 21(2):98-118, 1996.
34. Piehl K: Time course for refilling of glycogen stores in human muscle fibres following exercise-induced glycogen depletion. Acta Physiol Scand 90:297-302, 1974.
35. Nevill ME, et al: Effect of training on muscle metabolism during treadmill sprinting. J Appl Physiol 67(6):2376-2382, 1989.
36. Wootton SA, Williams C: Influences of recovery duration on repeated maximal sprints. *In: International Symposium on the Biochemistry of Exercise*. Boston: Human Kinetics Publishers, Inc., 1983.
37. Gaitanos GC, et al: Human muscle metabolism during intermittent maximal exercise. J Appl Physiol 75:712-719, 1993.
38. Holmyard DJ, et al: Effect of recovery on performance during multiple treadmill sprints. *In:* Reilly T, et al (eds): *Science and Football.* London: E&FN Spon, 1988.
39. Wyon MA: Challenging habit: planning and preparation, the art of periodisation and optimising performance. *In:* van der Linden M (ed): *Not Just Anybody and Soul*. Amsterdam: Uitgeveij International Theatre and Film Books, 2004, pp. 66-71.
40. Bompa T: *Periodization Training for Sports*. Champaign, Illinois: Human Kinetics Publishers, Inc., 1999.
41. Gotshalk L, Berger R, Kraemer W: Cardiovascular responses to high-volume continuous circuit resistance training protocol. J Strength Cond Res 18(3):760-764, 2004.
42. Borg G: Psychological assessments of physical effort. *In: International Symposium on Psychological Assessment in Sport, 1978. Wingate Institute for Physical Education and Sport.* Netanya, Israel: Wingate Institute for Physical Education and Sport, 1978.
43. Dudley G, Djamil R: Incompatability of endurance- and strength-training modes of exercise. J Appl Physiol 59(5):1446-1451, 1985.
44. Bell GJ, et al: Relationship between aerobic fitness and metabolic recovery from intermittent exercise in endurance athletes. Can J Appl Physiol 22(1):78-85, 1997.
45. Bangsbo J: Physiological factors associated with efficiency in high-intensity exercise. Sports Med 22(5):299-

305, 1996.
46. Billat L: Interval training for performance: A scientific and empirical practice. Special recommendations for middle- and long-distance running. Part I: aerobic interval training. Sports Med 31(1):13-31, 2001.
47. Cheetman ME, Williams C: High-intensity training and treadmill sprint performance. Br J Sports Med 21(2):14-17, 1987.
48. Hoffman JR, et al: The influence of aerobic capacity on anaerobic performance and recovery indices in basketball players. J Strength Cond Res 13(4):407-411, 1999.
49. Bangsbo J, et al: Muscle lactate metabolism in recovery from intense exhaustive exercise: Impact of light exercise. J Appl Physiol 77:1890-1895, 1994.
50. Smith JC, Hill DW: Contribution of energy systems during a Wingate power test. Br J Sports Med 25(4):4196-4199, 1991.
51. Billat L: Interval training for performance: A scientific and empirical practice: Anaerobic interval training. Sports Med 31(2):75-90, 2001.
52. Saltin B, Strange S: Maximal oxygen uptake: "Old" and "new" arguments for a cardiovascular limitation. Med Sci Sports Exerc 24(1):30-37, 1992.
53. Koutedakis Y, et al: The effects of rest and subsequent training on selected physiological parameters in professional female classical dancers. Int J Sports Med 20(6):379-383, 1999.
54. Baechle T: *Essentials of Strength and Conditioning*. Champaign, Illinois: Human Kinetics Publishers, Inc., 1994.
55. Fox E, et al: Frequency and duration of interval training programs and changes in aerobic power. J Appl Physiol 38:481, 1975.
56. Pollock ML, Gettman LR, Milesis CA, et al: Effects of frequency and duration of training on attrition and incidence of injury. Med Sci Sport Exerc 9(1):31-36, 1975.
57. American College of Sports Medicine: *ACSM's Guidelines for Exercise Testing and Prescription* (6th ed). Philadelphia: Lippincott Williams & Wilkins, 2000.