5-11-2018

Oxygen Consumption during Rehearsal and Performance in Collegiate Dancers

Mikela Nylander-French
The College at Brockport, mnfrench@icloud.com

Oxygen Consumption during Rehearsal and Performance in Collegiate Dancers

Senior Honors Thesis

Submitted in Partial Fulfillment of the Requirements
for Graduation in the Honors College

By
Mikela M.E. Nylander-French
Exercise Science Major

The College at Brockport
May 11, 2018

Thesis Director: Dr. Brooke Starkoff, Assistant Professor, Exercise Science

Abstract

Dance requires multiple physical attributes along with technical skill. One physical attribute that often gets left behind is aerobic condition even though it is a key component for optimal performance. Volume of oxygen consumption (VO_2) during dance class and rehearsal has been well documented. Dancers work at a lower VO_2 during class than rehearsal (5, 8, 9, 12, 16). However, there are few comparisons between rehearsal and performance of VO_2. PURPOSE: To identify and compare a difference in intensity during performance and rehearsal for collegiate dancers. METHODS: Seven collegiate dancers who were currently in rehearsal for an upcoming performance participated in this study. Five participants were females () and two were males (). On the first visit, each participant participated in a Bruce Protocol treadmill test (Table 1) using a portable metabolic cart. During the second visit, rehearsal data was obtained during scheduled rehearsal time while the dancers wore the portable metabolic cart. During the third visit, performance data was obtained in a performance like setting while the dancers wore the portable metabolic cart. A paired samples *t*-test was used to determine if there was significance between maximal volume of oxygen consumption (VO_{2max}) and VO_2 achieved during rehearsal and performance. RESULTS: Average VO_2 during rehearsal was 30.59 mL/kg/min (64.21% of VO_{2max}) and average VO_2 during performance was 33.49 mL/kg/min (70.07% of VO_{2max}) (Table 3). Significant difference was found between percent average VO_2 of VO_{2max} ($p=0.037$) and percent max VO_2 of VO_{2max} (45.36 mL/kg/min, 94.18% of VO_{2max} vs. 47.71 mL/kg/min, 99.19% of VO_{2max}, $p = 0.040$) during rehearsal and performance (Table 3). CONCLUSION: Dancers perform at intensities near or at their maximal VO_2. During performance the dancers were reaching 99% of their VO_{2max} compared to 94% of their VO_{2max}

during rehearsal. This indicates that rehearsal is not properly preparing dancers for the aerobic component of performance.

Introduction

Dancing requires great physical demand. Not only must dancers be technically skilled but they must also be aerobically conditioned. Dance is classified as an intermittent exercise, characterized by a mixture of short sets of explosive moves and continuous adagio (in slow tempo) movement that requires sustained technical precision (5). There are multiple physical attributes that a dancer must have to be able to perform such movements. Fitness for dance requires: 1) muscular power for performing explosive jumps and leaps, 2) muscular endurance for performing movements such as small sets of jumps (allegros) the require high power output for up to 30 to 60 seconds, and 3) cardiorespiratory endurance for low intensity exercises such as slow movements with wide range of motion (grand adage) (5). These fitness requirements rely on the utilization of various metabolic pathways. Muscular power reserve and muscular endurance use energy from the anaerobic pathways, while cardiorespiratory endurance utilizes aerobic oxidative pathways.

Although muscular power and muscular endurance are critical in dance, cardiorespiratory endurance is often overlooked when dancers train for performance. Cardiorespiratory (aerobic) endurance requires uptake, transportation, and utilization of oxygen to release energy for muscular work. Aerobically conditioned individuals are able to efficiently transport oxygenated blood to working muscles that perform more rigorously for longer lengths of time. Aerobic condition is often measured as the maximal volume of oxygen consumed (VO_{2max}) and is the greatest predictor of all-cause mortality (1). Aerobic health and, thus, aerobic conditioning is essential and a key requirement for dancers to achieve optimal performance capacity. In fact, it has been shown that the level of technical ability is highly correlated with a higher VO_{2max} as well as with a higher anaerobic threshold (AT) (8).

Dance training primarily takes place within technique class along with some various supplemental classes depending on the style of dance. Outside of class, dancers also partake in hours of rehearsal when preparing for a performance. It has been suggested that in ballet class work, particularly at the barre (e.g., plies, tendus), dancers only achieve low to moderate aerobic intensities (12). Dancers have been observed to use a lower percentage, approximately 50% of their VO_{2max}, during dance class compared to rehearsal (9). This is due to the focus on practicing and perfecting technique during class rather than preparing aerobically for performance. For dancers, rehearsal is an opportunity to learn new choreography and prepare for upcoming performances. Similar to technique class, rehearsal places a large focus on precision and clarifying movements specific to the performance. Only toward the end of a rehearsal period does the intensity increase to mimic a performance setting. Subsequently, additional training specific to improving aerobic capacity becomes a key component for optimal performance for dancers. Rarely do dancers train or rehearse at intensities similar to what they achieve during a performance. This is unlike other athletes, however, who tend to progressively increase training intensities over time to at or above competition intensities to elevate their physiological and performance capacity (3).

While dancers have been observed to work at a considerably lower level of their VO_{2max} during class (5, 8, 9, 12, 16), limited research exists on comparing VO_2 during rehearsal and performance. This is mainly due to lack of equipment and the location of dance performances (16). Furthermore, the percentage of VO_{2max} at which dancers perform during rehearsal and performance could not be identified in any published studies. The aim of this study was to identify and compare a difference in intensity during performance and rehearsal in collegiate dancers. By measuring the percentage of VO_{2max} at which dancers are rehearsing and performing, potential differences between these two settings can be elucidated. Based on previous research (5, 8, 9, 12, 16), we hypothesize that dancers will achieve a higher level of intensity during performance compared to rehearsal.

Methods

Subjects

Collegiate dancers who were in rehearsal for an upcoming performance (within 6-8 weeks) participated in this investigation. There were seven participants, 5 females (Age: 22.4 ± 2.61 years, BMI: 22.54 ± 1.45 kg/m^2, VO_{2max}: 45.64 ± 1.90 mL/kg/min) and 2 males (Age: 19.5 ± 0.71 years, BMI: 21.16 ± 0.21 kg/m^2, VO_{2max}: 55.45 ± 4.17 mL/kg/min). Six out of the seven dancers were undergraduate dance majors and one was a graduate student in the department of dance at an east coast college. All dancers were free of cardiovascular, metabolic, or pulmonary disease and reported no current musculoskeletal injuries as determined by a Health History Questionnaire (HHQ) prior to testing. All procedures were approved by the Institutional Review Board.

Preliminary Testing

After providing written informed consent, each participant participated in a Bruce protocol treadmill test (Table 1). The criteria for test termination was volitional termination by the subject due to exhaustion. After the completion of each test, the subjects completed a cool-down on the treadmill at their own desired speed with zero grade. The criteria for VO_{2max} were the attainment of at least three of the following: 1) a plateau in oxygen consumption with increasing workload, 2) a respiratory exchange ratio (RER) greater than 1.051, 3) heart rate within 10-12 beats per minute (bpm) of age predicted max heart rate, and 4) a rate of perceived exertion (RPE) above 17 (2). We determined the value of VO_{2max} by choosing the highest VO_2 value within the last 30 seconds of the test.

Table 1. Bruce Treadmill Protocol (4)

Stage	Time (min)	Speed (mph)	Grade (%)
1	0 – 3	1.7	10
2	3 – 6	2.5	12
3	6 – 9	3.4	14
4	9 – 12	4.2	16
5	12 – 15	5.0	18
6	15 – 18	5.5	20

min = minutes, mph = miles per hour, % = percent

An oro-nasal face mask and head strap (Hans Rudolf Oro-Nasal reusable, Shawnee, Kansas) were used to collect expired gasses. Respiratory-metabolic data (VO_2, VCO_2, and RER) were determined every second using an open-circuit spirometry system and on-line computer. Inspired ventilation and expired gasses were measured with a portable metabolic cart (COSMED, Rome, Italy). Heart rate was assessed during each testing systems using a Polar heart-rate monitor (Polar Electronic, Bethpage, NY) attached to the portable metabolic cart. Raw data were wirelessly transmitted to an associated laptop where values were observed in real time.

The pneumotachometer and all analyzers were calibrated prior to testing as recommended by the manufacturer with a 3-L calibration syringe and with room and standard gases of known composition, respectively.

Experimental Testing

Rehearsal

We obtained rehearsal data for each dancer during the scheduled rehearsal time in the rehearsal studio. The dancers rehearsed their piece once while wearing the portable metabolic system and heart-rate monitor.

Performance

We obtained performance data during a performance like setting, such that dancers were in costume and on stage with lights and sounds. The dancers performed their piece once while wearing the portable metabolic system and heart-rate monitor.

Statistical Analysis

Descriptive data identifying average VO_2, average percent of VO_{2max} achieved, maximal VO_2 obtained, and percentage of VO_{2max} achieved at maximal VO_2 are listed as means ± standard deviation (SD). Significance was set a priori at $p < 0.05$. A paired samples t-test using SPSS version 24 (IBM, Chicago, IL) was used to determine if there was significance between VO_2 achieved during rehearsal and performance. Furthermore, t-tests were used to assess differences in maximal oxygen consumption achieved during rehearsal and performance, PACES score after rehearsal and performance, and pain scale score after rehearsal and performance.

Results

Seven collegiate dancers from an east coast college dance department participated in the study. Five participants were female and two were male. Subject descriptive data is shown in Table 2. Table 3 displays the aerobic capacity achieved during rehearsal and performance. Percentages of VO_2 achieved during rehearsal and performance are displayed in Figure 1.

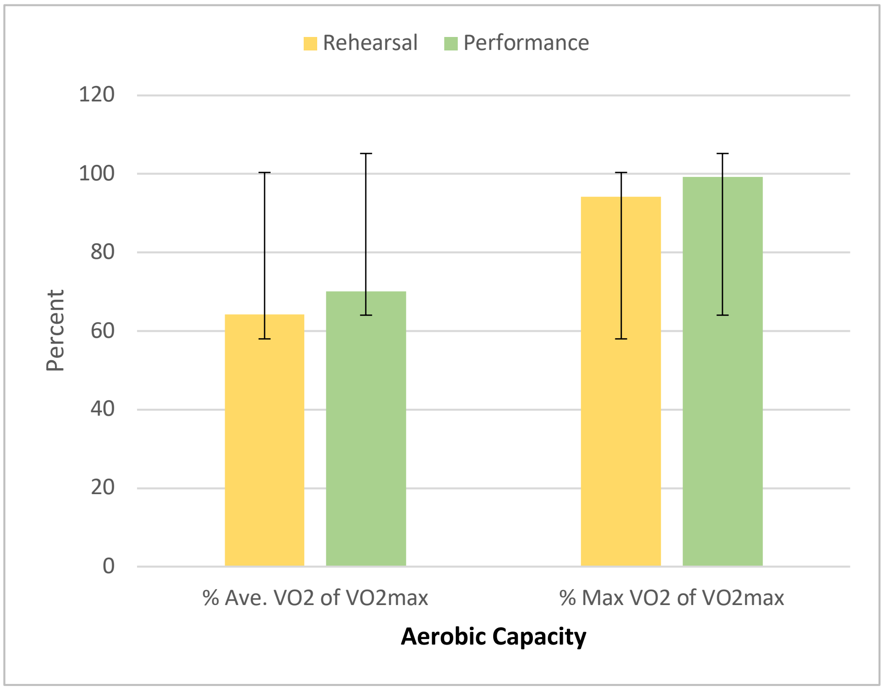

Figure 1. Percentage of VO_2 achieved during dance rehearsal and performance.

Average VO_2 during rehearsal was 30.59 mL/kg/min (64.21% of VO_{2max}) and average VO_2 during performance was 33.49 mL/kg/min (70.07% of VO_{2max}) (Table 3). A significant difference was observed between percent average VO_2 of VO_{2max} ($p = 0.037$). Maximal VO_2 achieved during rehearsal was significantly lower compared to the maximal VO_2 during performance (45.36 mL/kg/min, 94.18% of VO_{2max} *vs.* 47.71 mL/kg/min, 99.19% of VO_{2max}, $p = 0.040$) (Table 3).

Table 2. Descriptive data of the study population.

	All (N = 7)	Females (N = 5)	Males (N = 2)
Age (yrs.)	21.6 ± 2.57	22.4 ± 2.61	19.5 ± 0.71
Height (cm)	168.0 ± 10.2	163.8 ± 8.46	178.7 ± 4.74
Weight (kg)	62.43 ± 5.22	60.38 ± 4.52	67.55 ± 2.90
BMI (kg/m^2)	22.15 ± 1.36	22.54 ± 1.45	21.16 ± 0.21
VO_{2max} (mL/kg/min)	48.44 ± 5.31	45.64 ± 1.90	55.45 ± 4.17

yrs. = years, cm = centimeters, kg = kilograms, kg/m^2 = kilograms per meter squared mL/kg/min = milliliters per kilogram per minute

Table 3. Aerobic capacity measured during rehearsal and performance.

	Rehearsal	Performance
Avg. VO_2 (mL/kg/min)	30.59 ± 4.7	33.49 ± 6.0
% Avg. VO_2 of VO_{2max}	64.21 ± 13.3*	70.07 + 15.2*
Max VO_2 (mL/kg/min)	45.36 ± 4.0	47.71 ± 3.6
% Max VO_2 of VO_{2max}	94.18 ± 9.5^	99.19 ± 9.9^

mL/kg/min = milliliters per kilogram per minute, * p = 0.037, ^ p = 0.040

Discussion

The objective of this study was to compare oxygen consumption in collegiate dancers during rehearsal and performance. We observed that dancers achieve nearly 100% of their VO_{2max} during performance. During performance, the dancers were reaching 99% of their VO_{2max} and averaging 70% of their VO_{2max} throughout the performance. Several dancers were also reaching above 100% of their VO_{2max} during performance. In comparison, during rehearsal the dancers were reaching 94% of their VO_{2max} and averaging 64% of their VO_{2max}. This data confirms our hypothesis that the dancers reach a higher level of intensity during performance than rehearsal. More importantly though, not only were dancers working at a higher intensity during performance, they were also reaching up to 100% of their VO_{2max}.

Many studies have confirmed that dancers reach a higher level of intensity in rehearsal than class (5, 8, 9, 12, 16). Similarly, Wyon et al. (2004) observed that dancers had increased oxygen uptake during performance compared to rehearsal and class. This may be due to the fact that the main focus of class and rehearsal is to practice and perfect technique and choreography rather than achieve high intensities to stimulate cardiovascular adaptations. This is different than how many other athletes train, who focus on training general fitness, sport-specific fitness, technical skills, tactical abilities, psychological factors, health maintenance, and injury prevention all together (3).

We can ascertain from our results that rehearsal does not aerobically prepare dancers for performance. It is important for athletes to work at 75-100% of their VO_{2max} to improve their cardiorespiratory endurance with intermittent bouts of vigorous exercise (1). Denadai et al. (2006) observed that high intensity interval training (HIIT) at 100% of VO_{2max} led to a greater improvement in VO_{2max} after a four-week training program. According to Koutedakis et al. (2004), although 20 minutes of vigorous intensity exercise can improve the aerobic system, it is probable that most dance activities do not provide sufficient stimulus to bring about such adaptations. This is in contrast to other athletes who train above the necessary intensities needed for competition. Many athletes also spend a considerable amount of time cross training, such as an additional strength and condition program separate from their sport specific training (17).

Furthermore, dance has an extremely high rate of injury. Data gathered from multiple studies showed that within 2617 ballet dancers, 7332 musculoskeletal injuries were reported (13). In fact, the period prevalence of musculoskeletal injuries out of 2815 professional dancers from data gathered from 19 studies was 280% (13). While injuries may be sustained through a myriad of actions, approximately 60-76% of dance-related injuries are characterized as 'overuse' injuries (14). Most musculoskeletal injuries are soft tissue injuries such as sprains, strains, and tendinopathies (13). However, it is important to mention that these kinds of injuries may be associated with fatigue, which can be related VO_{2max} (15).

Fatigue has been defined as "an acute impairment of exercise performance that includes both an increase in the perceived effort necessary to exert a desired force or power output and the eventual inability to produce that force or power output" (6). Within dance literature, several studies have reported that injuries occurred most often during the performance season (10). Dancers subjected to longer days of dancing (5 hours or more) were considerably more likely to have a stress fracture than those who danced less (less than 5 hours a day) (10). Additionally, injuries occur most often late in the day and late in the season, suggesting fatigue as a causal factor (10).

VO_{2max} can influence fatigue and the time it takes for an individual to reach fatigue. Slower oxygen uptake causes a faster increase in anaerobic byproduct buildup within the body during exercise. This increase of byproducts leads to greater neuromuscular fatigue. Temesi et al. (2017) observed that athletes with slow VO_2 kinetics experienced more peripheral fatigue, and, in particular more excitation–contraction coupling failure. One of these byproducts linked to increased neuromuscular fatigue is lactic acid accumulation. Lactate accumulation hinders the ability to maintain homeostasis and keep the pH levels stable and subsequently, the muscle cells become fatigued and lose their ability to contract (11). When muscle cells lose their ability to contract and suffer from neuromuscular fatigue, it greatly hinders athletic performance. Based off of this information, individuals with lower aerobic capacity have a higher chance of injury.

When compared to other athletes, dancers tend to have lower physical fitness and higher rates of injuries (9).

Understanding the influence of VO_{2max} on fatigue and subsequent risk of injury, it is vital for dancers to participate in cross training activities to improve, aerobic endurance. Many dancers spend additional time enhancing flexibility and muscular strength but are often unaware of the importance of aerobic training in their programing. It could be beneficial to dance departments, companies, and programs to incorporate strength and conditioning programs into their training regimens. This would allow dancers to continue with muscular endurance, power, and flexibility training, but also allow them to incorporate more cardiovascular training. Strength and conditioning coaches have been proven to be extremely beneficial for athletic programs. Incorporating strength and conditioning programs geared towards dancers with a focus on aerobic endurance could greatly improve dancers' VO_{2max} and performance as well as reduce fatigue and lower the overall risk of injury.

Conclusion

Dancers perform at intensities near or at their maximal VO_2. We observed that during performance the dancers were reaching 99% of their VO_{2max} and averaging 70% of their VO_{2max} throughout the performance while during rehearsal dancers were reaching 94% of their VO_{2max} and averaging 64% of their VO_{2max}. This indicates that rehearsal is not properly preparing dancers for the aerobic component of performance. Dancers also have extremely high rates of injuries, primarily from overuse and fatigue (10, 13, 14). Neuromuscular fatigue plays a vital role in higher risk of injury (6). Slower VO_2 kinetics also contributes to greater neuromuscular fatigue (15). The aerobic capacity of dancers is an extremely important element of their fitness requirements that is often ignored during training. The information obtained in this study indicates that it is vital for dancers to partake in additional supplemental aerobic training to prepare them for the aerobic demands of performance. It is beneficial for dancers to implore utilizing a strength and conditioning program geared to dancers with a focus on cardiorespiratory endurance. This will help increase aerobic endurance, which will prepare dancers for physical stresses experienced during performance and potentially lead to a decrease in fatigue and risk of injury.

References

1. *ACSM's Guidelines for Exercise Testing and Prescription*. (2018) (10th Edition). Wolters Kluwer.
2. Beam, W. C., & Adams, G. M. (2014). Maximal Oxygen Consumption. In *Exercise Physiology Laboratory Manual* (pp. 163–182). New York, NY: McGraw-Hill.
3. Bompa, T. O., & Buzzichelli, C. A. (2019). *Periodization: Theory and Methodology of Training* (6th ed.). Champaign, IL: Human Kinetics. Retrieved from http://books.google.com/books/about/Periodization_6th_Edition.html?id=WgxZDwAAQBAJ
4. Bruce, R. A. (1974). Methods of exercise testing: step test, bicycle, treadmill, isometrics. *The American journal of cardiology*, *33*(6), 715-720.
5. Cohen, J. L., Segal, K. R., Witriol, I., & McArdle, W. D. (1982). Cardiorespiratory responses to ballet exercise and the VO2max of elite ballet dancers. *Medicine and Science in Sports and Exercise*, *14*(3), 212–217.
6. Davis, J., & Bailey, S. (1997). Possible mechanisms of central nervous system fatigue during exercise. *Medicine & Science in Sports & Exercise*, *29*(1), 4557.
7. Denadai, B. S., Ortiz, M. J., Greco, C. C., & de Mello, M. T. (2006). Interval training at 95% and 100% of the velocity at VO2 max: effects on aerobic physiological indexes and running performance. *Applied Physiology, Nutrition, and Metabolism*, *31*(6), 737–743. https://doi.org/10.1139/h06-080
8. Guidetti, L., Gallotta, M., Emerenziani, G. P., & Baldari, C. (2007). Exercise Intensities during a Ballet Lesson in Female Adolescents with Different Technical Ability. *International Journal of Sports Medicine*, *28*, 736–742. https://doi.org/10.1055/s-2007-964909

9. Koutedakis, Y., & Jamurtas, A. (2004). The dancer as a performing athlete: physiological considerations. *Sports Medicine*, *34*(10), 651–661.
10. Liederbach, M., Schanfein, L., & Kremenic, I. J. (2013, September). What Is Known About the Effect of Fatigue on Injury Occurrence Among Dancers? [Text]. Retrieved May 8, 2018, from http://www.ingentaconnect.com/content/jmrp/jdms/2013/00000017/00000003/art00003;jsessionid=1qwi3hxvs7hm7.x-ic-live-01
11. McArdle, W. D., Katch, F. I., & Katch, V. L. (2014). *Exercise Physiology: Nutrition, Energy, and Human Performance* (8th ed.). Netherlands: Wolters Kluwer.
12. Rodrigues-Krause, J., Krause, M., Cunha, G. dos S., Perin, D., Martins, J. B., Alberton, C. L., … Reischak-Oliveira, A. (2014). Ballet dancers cardiorespiratory, oxidative and muscle damage responses to classes and rehearsals. *European Journal of Sport Science*, *14*(3), 199–208. https://doi.org/10.1080/17461391.2013.777796
13. Smith, T. O., Davies, L., de Medici, A., Hakim, A., Haddad, F., & Macgregor, A. (2016). Prevalence and profile of musculoskeletal injuries in ballet dancers: A systematic review and meta-analysis. *Physical Therapy in Sport*, *19*, 50–56. https://doi.org/10.1016/j.ptsp.2015.12.007
14. Stassijns, G., Uijttewaal, J., & Brabander, L. V. (2015). Musculoskeletal Injuries in Dancers and Musicians. In *Nuclear Medicine and Radiologic Imaging in Sports Injuries* (pp. 949–970). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-46491-5_43
15. Temesi, J., Maturana, F. M., Peyrard, A., Piucco, T., Murias, J. M., & Millet, G. Y. (2017). The relationship between oxygen uptake kinetics and neuromuscular fatigue in high-intensity cycling exercise. *European Journal of Applied Physiology*, *117*(5), 969–978. https://doi.org/10.1007/s00421-017-3585-1
16. Wyon, M., Abt, G., Redding, E., Head, A., & Sharp, C. (2004). Oxygen uptake during of modern dance class, rehearsal and performance. *Journal of Strength and Conditioning Research*, *18*(3), 646–649.
17. Young, W. B. (2006). Transfer of Strength and Power Training to Sports Performance. *International Journal of Sports Physiology and Performance*, *1*(2), 74–83. https://doi.org/10.1123/ijspp.1.2.74