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A comparison of the aerobic cost and muscle use in aerobic dance to the energy costs and muscle use on treadmill, elliptical trainer and bicycle ergometry

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Objective: To determine the energy consumed and muscle use during dance compared to different standard exercise devices.
Design: Longitudinal study.
Methods: Fifteen female subjects were evaluated to assess the energy cost and muscle activity during a 20 minute dance video compared to treadmill, elliptical track and bicycle ergometry. The later 3 forms of exercise were accomplished in four, 5 minute bouts at different intensities of exercise. Subjects were in the age range of 22-24 years old, were free of cardiovascular disease and did not have any neurological injuries. They were not sedentary and exercised at least twice a week. During the exercise, muscle activity was measured by the electromyogram recorded by surface electrodes on 6 muscle groups. A Cosmed metabolic cart was used to measure oxygen consumption during the exercise.
Results: The aerobic dance video that was tested here was equivalent to a hard workout on any of the 3 exercise modalities. The dance routine was equivalent in terms of energy consumed to running at 225 watts of work or running for 20 minutes at a speed of 2 meters per second (4.47 miles per hour). Compared to the bicycle, it was equivalent to cycling at 112 watts for 20 minutes (2.25 kpm), and for the elliptical trainer, dance was equivalent to 435 watts. Concerning muscle use, the dance routine was the most balanced for upper, core and lower body muscles. Although the elliptical trainer was close, it required muscle less muscle use.
Conclusion: A good dance video can be more effective than standard exercise equipment.

Key Words: Aerobic exercise, Exercise, Exertion, Metabolism

Introduction

Exercise has always been the best remedy for obesity and the prevention of senescence of the cardiovascular system and metabolic diseases like diabetes [1-4]. Increasing daily exercise to at least 1 hour per week has been suggested by many federal agencies including NIH and the American Diabetes Association [5-9]. But most people show poor compliance for exercise. While their intensions are good, they start an exercise or diet program and then soon drop out [10-15].

Different types of exercise are often used. Many types of exercise such as skiing and cross country running are performed outdoors. These types of aerobic exercise offer good training in that they decrease caloric intake and causes a sustained increase in caloric output [16]. The sustained aerobic stress on the heart and the cardiovascular system increases blood pressure and heart rate and causes both increased cardiovascular toning and increased basil metabolism during and after exercise (EPOC) [17,18]. In addition, the immune

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system increases activity with regular exercise [19]. But many people do not have the time for outdoor exercise. Therefore, there are many types of indoor activities. These include cycle ergometry, treadmill running, and elliptical tracks trainers and other exercise devices.

Each type of exercise has a benefit on cardiovascular training and fitness. The easiest is cycle ergometry since the body weight is supported. Here all of the activity of muscles is to rotate the peddles and not support body weight [20]. This type of exercise is good for people who have arthritis or other disorders where supporting body weight makes accomplishing exercise difficult [21]. It can result in substantial training of muscle and the cardiovascular system.

Treadmill exercise uses large muscle groups and the work accomplished is increased as a function of body weight [22]. Like bicycle ergometry, the workload can be increased by increasing the speed and the load. Here the load is adjusted by increasing the incline angle of the treadmill. Numerous studies have shown the cardiovascular benefit and increase in muscle tone and strength with treadmill running [23,24]. However, treadmill ergometry is often boring since the person remains essentially stationary.

To increase the muscle used in the exercise, elliptical trainers have been used in health spas and at home. These involve more fluid motion where the exercise is a mixture between a step trainer and a bicycle and treadmill [25]. Body weight is not supported during the exercise. By using stepping exercises the elliptical trainer uses a flywheel like a bicycle and allows forward and reverse motion to increase muscle activity in the lower body and handles for the arms [26]. Elliptical trainers have been studied well and have been shown to have good benefits on the muscoskeletal and cardiovascular systems. They involve some upper body as well as lower body exercise. But they also can be boring.

Many of the newer exercise regimes include dance videos. The concept here is that dance offers aerobic training in the upper and lower body together allowing for a better and more thorough workout. Dance has been shown to have improvements in the immune system and the cardiovascular system [27,28]. An old axiom in exercise is that you can only train the muscles that are being used by an exercise regime. Treadmill work, for example, will train the legs but not the arms and chest muscles. Dance uses extensively core muscles as well as muscles in the legs and arms [29,30]. This should increase caloric expenditure and result in a better training program. An additional benefit is the fun of dancing, certainly much less boring than treadmill exercise. On all of these exercise modalities, it is easy to analyze caloric expenditure by measuring oxygen consumption.

When oxygen use and carbon dioxide production are measured, the respiratory quotient during exercise can be assessed. This provides useful information as to the fuel used during the exercise [31]. If the RQ=1, then carbohydrates are being used by the body whereas with an RQ of 0.7, fats are being burned. The oxygen uptake (oxygen use x ventilation) of the body can also be used with the RQ to determine caloric expenditure [31]. Generally for each liter of oxygen burned, 5 kcal of energy is used [32]. Muscle use is somewhat more difficult to determine.

Historically, the electromyogram (EMG), the electrical activity from underlying muscles, can be used to assess muscle activity [33,34]. The root-mean-square (RMS) average of the EMG is a useful tool with which to assess muscle activity. There is a linear relationship between the EMG amplitude (RMS) and the activity of muscle [34]. However, because different electrode placements and different blood flows in skin and muscle can alter the recorded EMG amplitude, The EMG must first be calibrated and then normalized [33,35-37]. This is accomplished by placing each muscle in the center of its length (mid-range of motion) and then conducting a series of strength measurements. The recorded EMG is then used so that EMG during exercise is divided by the total EMG for that muscle to obtain the normalized EMG as a percent to muscle activity.

The purpose of the present investigation was to assess muscle use and oxygen consumption during aerobic dance compared to treadmill, an elliptical trainer, and bicycle ergometry.

Methods

Subjects

Fifteen female subjects in the age range of 22 to 24 years old participated in the study. Subjects were fit enough to participate in all 4 exercise modalities. Subjects must have ex-

Table 1. Demographics of subjects (N=15)

	Age	Height	Weight	BMI
Mean	23.9	167.7	66.8	23.7
SD	1.2	7.3	10.9	3.3

BMI: body mass index.

ercised in sports or weight lifting at least 2 times per week. Subjects were free of cardiovascular disease or neurological injury at the time of the experiment. The general characteristics of the subjects are in Table 1. All subjects signed a consent form and all procedures were approved by the Human Review Committee of Azusa Pacific University.

Methods

Blood pressure: Blood pressure was measured by auscultation of the left arm. An automatic blood pressure cuff was used on the wrist (Omron Hem 621, Schaumburg, IL, USA).

Heart rate: Heart rate was determined by the radial pulse by the blood pressure cuff mentioned above.

Carbon dioxide production and respiratory quotient and metabolism

A Cosmed model $Kb2^2$ (Cosmed, Chicago, IL, USA), was used to measure metabolic parameters. A Hans Rudolph mask was placed over the patients face and firmly secured so that no air would leak. A single air supply line supplied to the Cosmed metabolic cart using a turban flow meter placed on the Hans Rudolph mask was used to measure ventilation.

The Cosmed analyzer was calibrated in between each five subjects. Calibration involved calibration against room air and a standardized gas calibrated on a mass spectrometer with a concentration of 16% O_2 and 5% CO_2. The turban flow meter was calibrated with a three liter gas syringe. Barometric pressure and room humidity were used to correct all gas values to STPD (standard temperature and pressure). By entering the subject's height, age, weight, and sex, an algorithm in the Cosmed calculated the caloric expenditure, and based on the RQ, the percent carbohydrates and fats that were burned before, during, and after the exercise.

Determination of muscle activity

To determine muscle activity, the EMG was used. It was recorded by using two electrodes and a ground electrode placed above the active muscle [34,35,37-39]. The relation between tension in muscle and surface EMG amplitude was linear [37,40,41]. Thus, the amplitude of the surface EMG could be used effectively as a measure of activity of the underlying muscle by simply normalizing the EMG in terms of a maximal effort. Muscle activity was therefore assessed by first assessing the maximum EMG during a maximum effort to calculate the percent of muscle activity during the exercise. The electrical output from the muscle was amplified with a bio potential amplifier with a gain of 2,000 and frequency response that was flat from DC to 1,000 Hz (EMG 100 C amplifier, Biopac Inc., Goleta, CA, USA). The amplified EMG was digitized with a 24-bit analog to digital converter and sampled at a frequency of 1,000 samples/sec (MP 100, Biopac Inc.). The software to analyze the EMG was Acknowledge 4.1 (Biopac Inc.).

Exercise

Dance

The dance routines were a 20 minute aerobic dance video supplied by Savieer LP. It was a commercial video sold on the open market.

Treadmill: Treadmill exercise was accomplished on a Nordic Track treadmill.

Elliptic trainer: The elliptic trainer used was a e25s sole-elliptical trainer (Seattle Washington).

Bicycle Ergometer: The bicycle ergometer was a Monarch model 23 stationary monarch bicycle ergometer (Stockholm Sweden).

Procedures

Subjects participated in 4 series of experiments conducted on 4 separate days. The order of the experiments was at random. Subjects accomplished bicycle ergometry, elliptical training, and treadmill running or dancing in random order. Subjects accomplished 5 minutes of treadmill running at 3, 4.5, and 6 mph on a flat grade. The actual work done based on the subjects weight was 220, 291, 365 and 428 watts. For the exercise bicycle, subjects kept the speed constant on the peddles at 50 rpm and exercised in 5 minute bouts against a resistance of 0.5, 1, 1.5 and 2 kp. The actual workloads were 25, 50, 75 and 100 watts. For the elliptical trainer, they worked at 249, 298, 334, and 374 watts for 5 minute bouts. Finally, on a separate day, they used the dance video for 20 minutes. During these exercise bouts they had EMG electrodes placed over the hamstring, quadriceps, rectus abdominus, obliques, biceps and triceps muscles. On each day, they exerted a maximum effort for each muscle group at the beginning of each day while EMG was recorded. They also had their oxygen consumption recorded at rest and throughout the bouts of exercise.

Data analysis

Data analysis involved calculation of means and standard deviations. ANOVA was used to compare the different exercise types for EMG and oxygen consumption. The significance was $p < 0.05$.

Results

The results of the experiments are shown in Figures 1-13.

Oxygen use and fuel burned

As shown in Figure 1, the oxygen consumption increased linearly with the work accomplished up to about 2.5 liters per minute for the highest work load. The increase in oxygen consumption with load was significant (ANOVA, $p < 0.01$). At the highest workload, the oxygen consumption averaged 33.3+/-2.48 ml/kg body weight. This amounts to 9.5 METS. At the highest workload, the subjects used 697 watts of energy. The efficiency of treadmill running then was 16.1%. The fuel use started at the lowest load as mostly fat but at the heaviest loads was entirely carbohydrates as shown in Figure 2.

The oxygen consumed in relation to the energy used is shown in Figure 3 for the bicycle ergometer.

As was the case for the treadmill, energy use was significantly higher with an increase in work during the exercise (ANOVA, $p < 0.01$). As shown in Figure 3, the work at each load was significantly less than for the treadmill in Figure 1 (ANOVA, $p < 0.01$). However, the relationship between work accomplished and energy used was still linear. The slightly lower work seen here resulted in significantly higher fat burning as a fuel at the lowest workloads. But, by the highest workload, the subjects were using pure carbohydrates for fuel as shown in Figure 2. Comparing Figures 1 and 3, subjects used twice the energy per watt of energy used

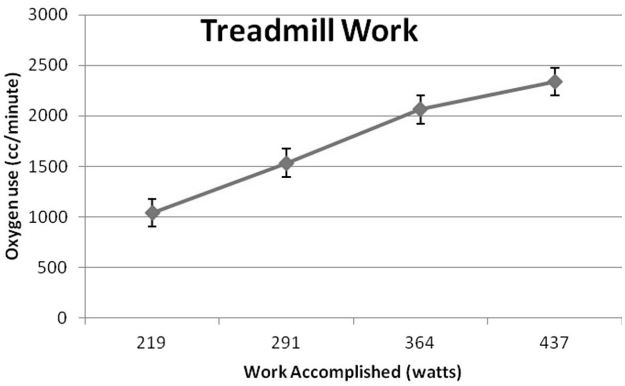

Figure 1. The relationship between the work accomplished on the treadmill and the oxygen consumption. Each point is the mean of 15 subjects +/- the SD. The equation of the regression is y=5.14x+255.

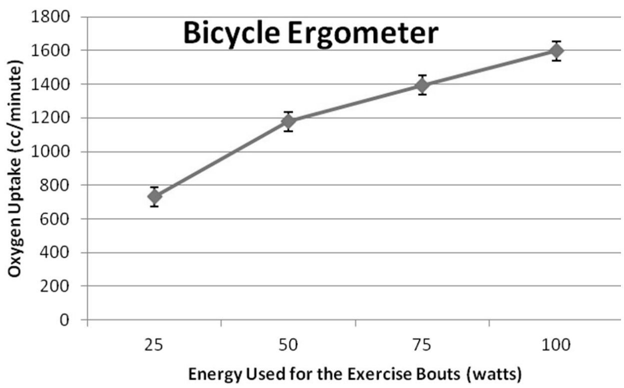

Figure 3. The relationship between the work accomplished on the bicycle ergometer and the oxygen consumption. Each point is the mean of 15 subjects +/- the SD. The regression equation showed y=12x+430.

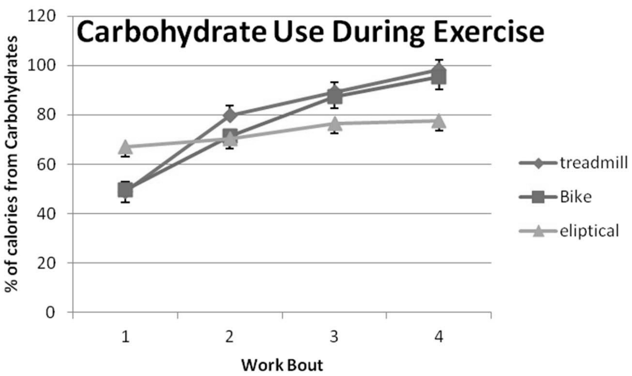

Figure 2. The relationship between the work accomplished on the treadmill, bicycle ergometer and elliptical trainer and the % carbohydrate burned. Each point is the mean of 15 subjects +/- the SD.

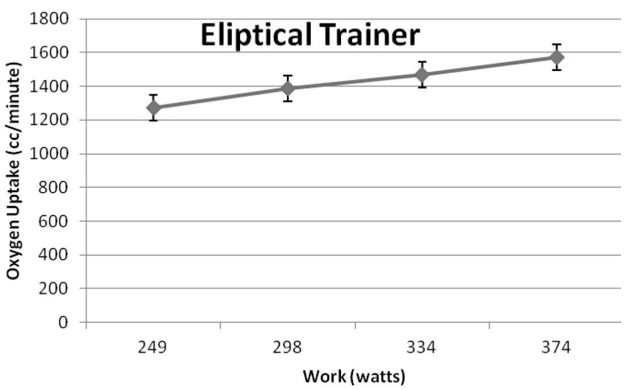

Figure 4. The relationship between the work accomplished on the elliptical trainer and the oxygen consumption. Each point is the mean of 15 subjects +/- the SD.

on the treadmill as was seen on the bicycle. The energy used here was 473 watts for efficiency at the highest workload of 21.3%.

As shown in Figure 4, the oxygen consumption increased linearly with the work accomplished up to about 1.6 liters per minute for the highest work load on the elliptical trainer. The increase in oxygen consumption with load was significant (ANOVA, $p < 0.01$). The fuel use started at the lowest load as mostly fat but at the heaviest loads was entirely carbohydrates as shown in Figure 2.

During the 20 minutes of dance, there was a fairly constant use of oxygen as shown in Figure 5. At the end of the dance video there was a cool down period such that there was a slight reduction in oxygen consumption.

As shown in Figure 5, the average calories burned during the exercise video was 8.69+/1.1 calories per minute. For the bicycle, the average calories burned during the heaviest workout bout was 7.99+/-0.9 calories per minute, for the treadmill for the heaviest workout the average calories burned was 11.6+/-1.8 calories per minute and for the elliptical trainer, the average calories burned was 7.85+/-1.3 calories per minute during the hardest of the 4 exercise bouts. In other words, the dance routine was equivalent in terms of energy consumed to running at 225 watts of work or running for 20 minutes at a speed of 2 meters per second (4.47 miles per hour). Compared to the bicycle, it was equivalent to cycling at 112 watts for 20 minutes (2.25 km), and for the elliptical trainer, dance was equivalent to 435 watts of work.

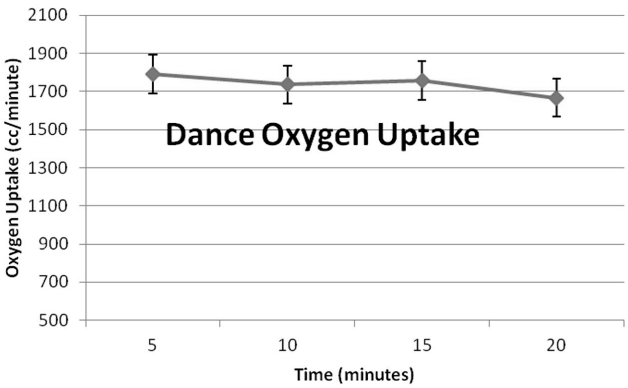

Figure 5. The relationship between time for the dance video and the oxygen consumption. Each point is the mean of 15 subjects +/- the SD.

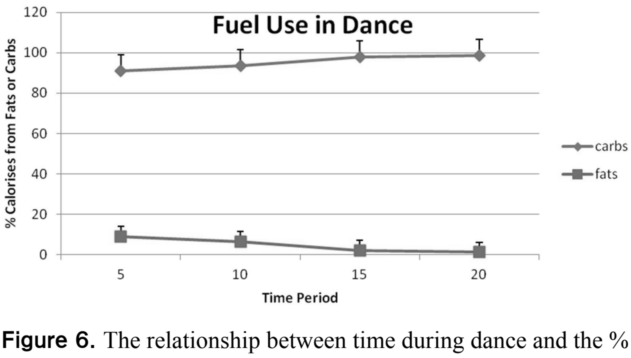

Figure 6. The relationship between time during dance and the % carbohydrates and fats burned. Each point is the mean of 15 subjects +/- the SD.

For the top 10% of the dance participants, the average oxygen consumed was 2,080 ml of oxygen per minute and for the top 20% it averaged 2,036 ml of oxygen per minute. On the average the dance workout burned 181 calories for the 20 minutes.

The fuel use during dance, Figure 6, showed the fuel to be largely carbohydrate metabolism.

Muscle use

The muscle use during the 20 minutes of dance is shown in Figure 7. The average use each 5 minutes was fairly constant and showed both upper and lower body muscle use. Thus as shown in Figure 7, for the entire 20 minutes, while much of the muscle use is in the lower body, core muscles and upper body muscles are used extensively. For the 20 minutes, the average muscle use for these 6 muscles was 27.1 % of the muscle.

For the bicycle, when looking at each progressive increase in work load, there was a progressive increase in muscle use (Figure 8). The greatest use was in the quadriceps muscles with some core activity increase and only minor

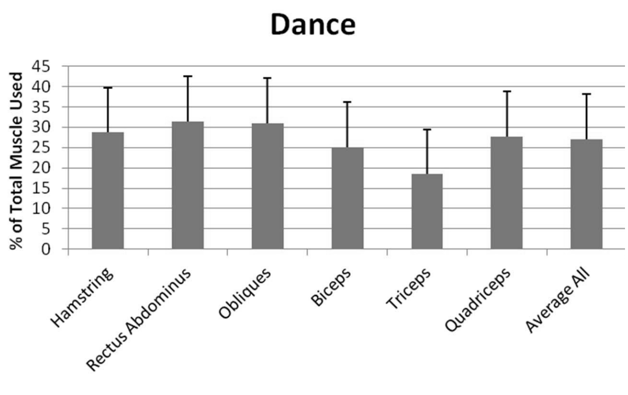

Figure 7. Muscle used during dance averaged for the 20 minute period. Each point is the mean +/- the SD for 15 subjects. Data is shown for the hamstrings, rectus abdominus obliques, quadriceps, hamstring muscles, the biceps and the triceps muscles.

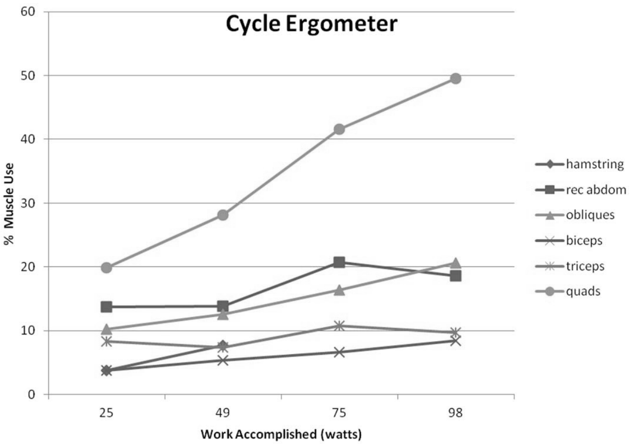

Figure 8. Muscle used during the cycle ergometer for the 20 minute period compared to workload. Each point is the mean +/- the SD for 15 subjects. Data is shown for the hamstrings, rectus abdominus obliques, quadriceps, hamstring muscles, the biceps and the triceps muscles.

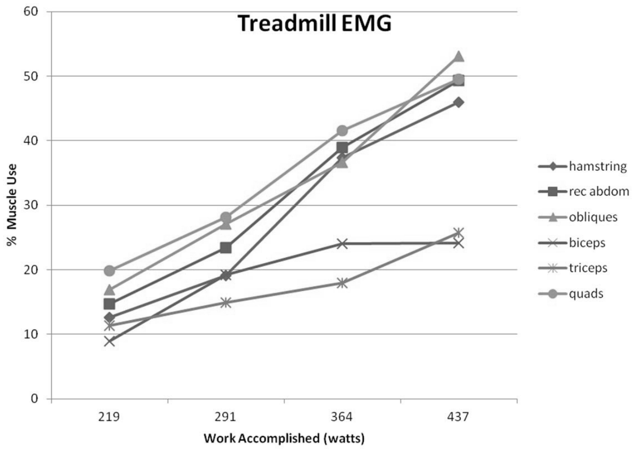

Figure 10. Muscle used during treadmill compared to work load for the four, 5 minute bouts of work. Each point is the mean +/- the SD for 15 subjects. Data is shown for the hamstrings, rectus abdominus obliques, quadriceps, hamstring muscles, the biceps and the triceps muscles.

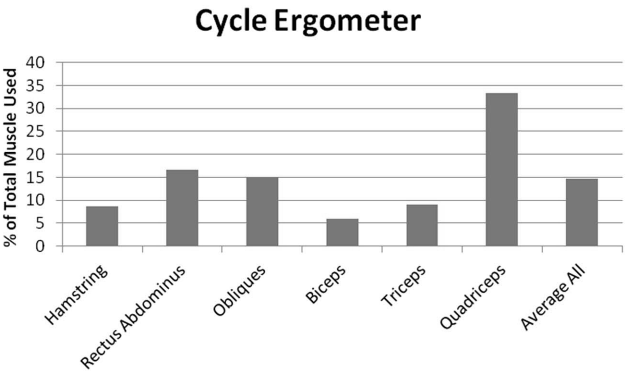

Figure 9. Muscle used during the cycle ergometer averaged for the 20 minute period. Each point is the mean +/- the SD for 15 subjects. Data is shown for the hamstrings, rectus abdominus obliques, quadriceps, hamstring muscles, the biceps and the triceps muscles.

Figure 11. Muscle used during treadmill averaged for the 20 minute period. Each point is the mean +/- the SD for 15 subjects. Data is shown for the hamstrings, rectus abdominus obliques, quadriceps, hamstring muscles, the biceps and the triceps muscles.

muscle use in the upper part of the body. When muscle use is averaged over 20 minutes (Figure 9) muscle use was also mainly in the legs. The average muscle activity over the 20 minutes was 14.8%, a figure significantly less than the exercise during dance.

Figures 10 and 11 shows the muscle use data from the treadmill. There was little muscle activity in the upper body muscles as might be expected. The average muscle activity with the lower body muscle was about 19% of the total muscle mass during these exercises.

Figures 12 and 13 show the data for the elliptical trainer EMG in relation to workload (Figure 12) and averaged over the 20 minute period (Figure 13). For the elliptical trainer there was use of the abdominals, the biceps and triceps and the leg muscles. In many ways it was more similar to dance than the other modalities. Overall, 18.8% of muscle activity was used on the 6 muscles over the 20 minutes compared to 27% on dance, a significantly higher muscle use and also more oxygen consumed in the dance routines.

Discussion

Obesity is an epidemic [42-44]. Increased body fat is associated with increased morbidity and mortality as well as reduced endothelial function even in a young population [12,42]. It is one of the leading causes of diabetes [42].

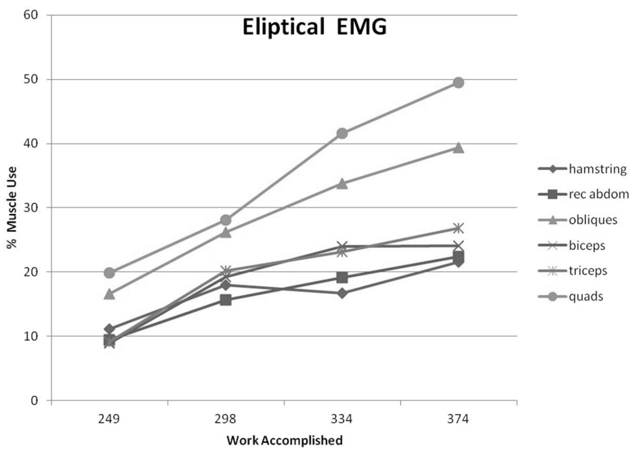

Figure 12. Muscle used during the elliptical trainer compared to work load for the four, 5 minute bouts of work. Each point is the mean +/- the SD for 15 subjects. Data is shown for the hamstrings, rectus abdominus obliques, quadriceps, hamstring muscles, the biceps and the triceps muscles.

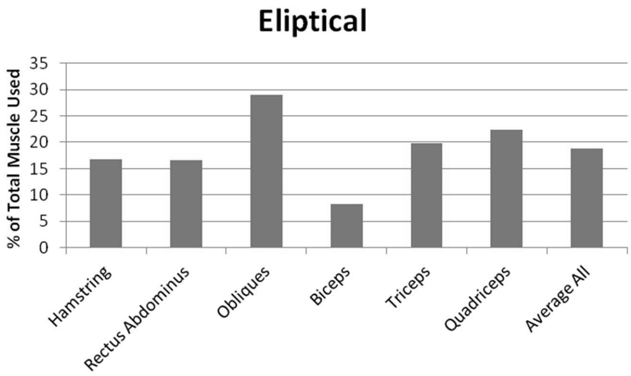

Figure 13. Muscle used during dance averaged for the 20 minute period. Each point is the mean +/- the SD for 15 subjects. Data is shown for the hamstrings, rectus abdominus, obliques, quadriceps, hamstring muscles, the biceps and the triceps muscles.

While it can cause serious health care issues, even in children, it is preventable by simply increasing exercise so that caloric intake is exceeded by caloric output [8,9,12,42].

But exercise sometimes can become routine and boring. Therefore, many people buy health club memberships and never use them. While exercise bicycles, treadmills and elliptical trainers are all common forms of exercise, they become very routine even to the dedicated user. Especially for women, dance is a popular form of exercise [27]. Dance has the advantage of using a larger percentage of the bodies' muscles, thus increasing the total workout and conditioning [45,46]. As shown in this investigation, bicycle ergometry is a very efficient form of exercise and has the advantage of supporting the body's weight. This is also a disadvantage in that predominantly the leg muscles exercise with little core and upper body activity. The calories expended are also low in comparison to the work accomplished. Studies have shown that bicycling at 50 rpm is the most efficient form of exercise that can be done; this makes it a poor candidate for toning and weight loss in that the work level is low as shown here [47].

Treadmill running is less efficient and uses some core muscles but predominantly the leg muscles [48]. The exercise uses sufficient calories for toning and weight loss but the upper body is used very little [49]. Therefore, for the treadmill or the bicycle, other exercises are usually added to these exercise modes to provide a balanced workout. The elliptical trainer was designed to be a more efficient means of exercising since it uses upper body muscles and lower body muscles as well as the core.

The dance video was a balanced exercise in terms of muscle use. It was similar to the elliptical trainer but better than the bicycle or treadmill. The fuel use was higher in carbohydrates due to the intensity of the whole body exercise. The stress is lower on the muscles and cardiovascular system due to a lower static component of the exercise. If dynamic exercise is conducted slowly, there is a considerable isometric component to the exercise that causes fuel use to switch to carbohydrates with light exercise and making the exercise inefficient [47,50]. If exercise is conducted, even at the same oxygen uptake, more quickly and with less loading on the muscle, the exercise becomes more aerobic in demand for energy and more fat is burned during the exercise. Dance would have a lower static component and less cardiovascular stress and allow a more efficient workout.

Oxygen consumption and muscle use in the top 10% and 20% of the subjects was also striking during the dance routine. For the top 10% of the dance participants, the average oxygen consumed was 2,080 ml of oxygen per minute and for the top 20% it averaged 2,036 ml of oxygen per minute. On the average the dance workout burned 181 calories for the 20 minutes.

For dance, there was better general use of all muscle sin the body and at higher levels than any of the other 3 exercises. The elliptical trainer was closest in the pattern of muscle activity but was about 1/3 less for the activity of the muscles and well less in energy costs of the work.

In summary

1) The dance video examined here had more balanced muscle use than was seen for the bicycle or treadmill or ellip-

tical trainer.

2) The dance video examined here was a good aerobic workout comparing to considerable load on the cycle ergometer, treadmill or elliptical trainer.

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