Cardiovascular and Metabolic Responses to Water Aerobics Exercise in Middle-Aged and Older Adults

Amy L. Nikolai, Brittany A. Novotny, Cortney L. Bohnen, Kathryn M. Schleis, and Lance C. Dalleck

Background: The purposes of this study were (1) to assess the cardiovascular and metabolic responses to water aerobic exercise and (2) to determine if water aerobics exercise meets the American College of Sports Medicine (ACSM) guidelines for improving and maintaining cardiorespiratory fitness. Methods: Fourteen men and women—mean ± SD age 57.4 ± 7.6 y, height 171.3 ± 7.8 cm, weight 89.9 ± 13.9 kg, body-fat percentage 32.5% ± 5.8%, and maximal oxygen uptake (VO$_{2\text{max}}$) 31.0 ± 8.3 mL · kg$^{-1}$ · min$^{-1}$—completed a maximal treadmill exercise test and a 50-min water aerobics session. Cardiovascular and metabolic data were collected via a portable calorimetric measurement system. Results: Mean exercise intensity was 43.4% of heart-rate reserve and 42.2% of maximal oxygen uptake reserve. Training intensity in metabolic equivalents was 4.26 ± 0.96. Total net energy expenditure for the exercise session was 249.1 ± 94.5 kcal/session. Conclusions: Results indicate that water aerobics is a feasible alternative to land-based exercise for middle-aged and older adults that fulfills the ACSM guidelines for improving and maintaining cardiorespiratory fitness.

Keywords: cardiorespiratory fitness, physical activity, maximal oxygen consumption, shallow-water exercise, hydrotherapy

Regular physical activity confers numerous health benefits including the prevention and control of hypertension, obesity, diabetes, dyslipidemia, and coronary artery disease. Physical activity may also lead to improved cardiorespiratory fitness provided that exercise intensity is adequate. Cardiorespiratory fitness, typically determined by maximal oxygen uptake (VO$_{2\text{max}}$), refers to the highest rate at which oxygen can be taken up and consumed by the body during intense exercise. Studies have consistently demonstrated an inverse relationship between VO$_{2\text{max}}$ values and risk of cardiovascular disease and all-cause mortality. In fact, it has recently been suggested that cardiorespiratory fitness should be employed as the ultimate marker for risk stratification and health outcomes.

Given its relationship to positive health, the parameters of an exercise program needed to improve cardiorespiratory fitness have been studied extensively, and subsequently well-defined guidelines have been published. The American College of Sports Medicine (ACSM) currently recommends 20 to 60 minutes of aerobic exercise 3 to 5 d/wk at an intensity of 64/70% to 94% of heart-rate maximum (HR$_{\text{max}}$), 40/50% to 85% of heart-rate reserve (HRR) or oxygen uptake reserve (VO$_{2\text{R}}$), and 12 to 16 rating of perceived exertion. In addition, the ACSM has recommended a target energy expenditure of 150 to 400 net kcal/d. Traditional forms of aerobic exercise include walking, jogging, and cycling.

However, individuals who have limiting physical conditions such as osteoarthritis, orthopedic problems, low back pain, or neuromuscular impairments may experience difficulty achieving the ACSM recommendations because of the physical demands of land-based exercises modalities. In part, for these reasons aquatic exercise and water aerobics have become an increasingly popular, alternative form of aerobic exercise for those who are physically limited, injured, and/or older. Although there is a considerable body of literature concerning the various health benefits associated with aquatic exercise, research focused on the specific physiological and metabolic responses to water aerobics is relatively sparse and has mostly been completed with younger participants. We are aware of only 2 studies that have dealt with the physiological responses to water aerobics exercise in middle-aged and older adults. In 2000, D’Acquisto et al investigated the metabolic and cardiovascular demands of shallow-water activity in 60- to 80-year-old women. They reported that
40 minutes of shallow-water exercise elicited mean HR\textsubscript{max} responses of 66% to 78%, which fulfills the ACSM intensity guideline for improving and maintaining cardiorespiratory fitness. Campbell et al\textsuperscript{14} compared the physiological and metabolic demands of 40 minutes of shallow-water exercise in young and older women. For the older women, cardiovascular demands averaged 70% to 75% HR\textsubscript{max}, while the metabolic demands equaled 4 to 6 metabolic equivalents (METs). It was concluded that shallow-water exercise elicited cardiovascular and metabolic responses that met ACSM guidelines for health benefits.

Two shortcomings of the above-mentioned studies were that HR\textsubscript{max} was estimated, not actually measured, and there were only limited samples of expired gas collected for determining the metabolic demands of water exercise.\textsuperscript{13,14} The advent of lightweight, portable metabolic systems such as the CosMed K4 b2 now makes it possible to gather continuous gas-exchange data during physical activities and consequently obtain more precise metabolic data. The lack of research concerning the physiological responses to water aerobic exercise in middle-aged and older-adult populations and the need to strengthen the methodology from previous studies prompted the present investigation. The purposes of this study were (1) to assess the cardiovascular and metabolic responses to water aerobic exercise and (2) to determine if water aerobics exercise meets the ACSM guidelines for improving and maintaining cardiorespiratory fitness. We hypothesized that water aerobics would meet the recommended guidelines for moderate-intensity exercise as stated by the ACSM.

Methods

Participants

Fourteen nonsmoking men and women (42 to 65 years old) currently participating in a water aerobics class offered as part of a local community fitness program were recruited for the study. Before participation in the community fitness program, participants were risk stratified according to the criteria defined by the ACSM.\textsuperscript{5} Those who were risk stratified into moderate- or high-risk categories were required to obtain approval by their physician to complete moderate-intensity physical activity and also supervised maximal exercise tests. All maximal exercise tests were supervised by the principal investigator, who had 10 years experience of stress testing in cardiac-diseased individuals. Before participation in the study, each participant signed an informed-consent document and completed a health-history questionnaire. The university’s institutional review board approved this study.

Procedures

All measurements were obtained on nonconsecutive testing days between 6 and 8 AM. Day 1 consisted of anthropometric measures, measurement of resting metabolic rate, and the maximal exercise test. Day 2 consisted of the water aerobics exercise testing session. Participants were instructed to refrain from strenuous activity and alcohol and caffeine consumption 24 hours before each testing session. Participants were also encouraged to consume a light breakfast before each testing session. Testing sessions were separated by 2 to 10 days.

Anthropometric Measurements. Participants were weighed to the nearest 0.1 kg on a medical-grade scale and measured for height to the nearest 0.5 cm using a stadiometer. Percent body fat was determined via skinfolds.\textsuperscript{15} Skinfold thickness was measured to the nearest ± 0.5 mm using a Lange caliper (Cambridge Scientific Industries, Columbia, MD). All measurements were taken in duplicate, or until measurements were within 1 to 2 mm, on the right side of the body using standardized anatomical sites (3-site) for men and women.

Instrumentation. Resting metabolic rate and oxygen uptake during the water aerobic exercise session and maximal exercise test were measured using a CosMed K4 b2 (Rome, Italy) portable calorimetric measurement system. The CosMed system has been previously validated over wide ranges and intensities of physical activity.\textsuperscript{16,17} For all data collection a face mask (Hans-Rudolph, Kansas City, MO) covering the mouth and nose of the participant was connected to a bidirectional digital turbine flowmeter with an optoelectrical reader and attached to the participant with a mesh hair net and Velcro straps. The testing unit was connected to the participant’s chest via a harness for measurement of resting metabolic rate and VO\textsubscript{2max}. During the water aerobics exercise session, the portable system was hand held by an investigator in a small waterproof Tupperware container (Figure 1). Calibration of the CosMed system was completed before each individual testing session according to manufacturer’s guidelines. Breath-by-breath data were downloaded to a Windows-based computer containing CosMed version 6 software and then subsequently transferred and analyzed with Microsoft Excel and Statistical Package for the Social Sciences, version 15.0 (SPSS, Inc, Chicago, IL).

Resting Metabolic Rate and Maximal Exercise Test. After being connected to the CosMed system, participants rested quietly for 5 minutes in a seated position. The last minute of breath-by-breath and heart rate (HR) data were averaged and considered to be resting metabolic rate (VO\textsubscript{2R}) and resting HR. On a Woodway Desmo Pro treadmill (Waukesha, WI), a modified Balke protocol was performed with subjects selecting a comfortable walking or jogging speed that could be maintained for the duration of the test. After resting expired gases were measured for 2 minutes, subjects were gradually brought to the selected walking or jogging speed for the first minute of the test, which was then maintained throughout the duration of the test. The first 3
minutes of the protocol were performed at 0% grade; thereafter, each minute the treadmill grade was increased by 2% until volitional fatigue was reached. The criteria for attainment of VO₂max were 2 out of 3 of the following: (1) a plateau (ΔVO₂ ≤ 150 mL/min) in VO₂ with increases in workload, (2) maximal respiratory-exchange ratio ≥ 1.1, and (3) maximal HR within 15 beats/min of the age-predicted maximum (220 – age). VO₂max was defined as the highest VO₂ obtained over any continuous 30-second time period, provided 2 of the 3 aforementioned VO₂max criteria were attained. Continuous HR measurements were obtained using a Polar F1 HR monitor (Polar Electro Inc, Woodbury, NY) that was interfaced with the CosMed system.

**Water Aerobics Exercise Test.** Participants engaged in a 50-minute water aerobics class in chest-deep water. They were instructed to arrive 10 minutes before the start of the 6:10 AM or 7:10 AM class for a series of pretesting measures, including attachment of the HR monitor and portable metabolic analyzer, familiarization with the breathing apparatus, and an explanation of testing instructions and precautions. Participants were encouraged to complete the water aerobics class at their own self-selected intensity. Furthermore, they were instructed to select a workload that would allow them to continue to carry on conversation and not elicit undue fatigue or discomfort. Water aerobics classes were led by the same experienced water aerobics instructor. Each session began with a 5-minute warm-up consisting of light-intensity jogging and other repetitive total-body movements and static stretching. The warm-up was followed by a 25-minute cardio workout consisting of 20- to 30-second bouts of various aerobic movements. Abdominal exercises were performed for 5 minutes after the cardio portion of the class. Participants then completed a 5-minute upper-body workout using resistance bands. The class concluded with a 5-minute cool-down consisting of upper- and lower-extremity static stretching. Water temperature ranged from 26.7 to 28.4°C.

**Exercise Intensity and Metabolic Calculations.** Individual HRR was determined as the difference between resting and HRmax values. Likewise, individual VO₂R was determined as the difference between resting and maximum VO₂ values. The metabolic equivalent (MET) for water aerobics exercise was determined by dividing the exercise VO₂ by resting VO₂ for the workout portion of class (warm-up and cool-down metabolic data were omitted in this analysis). Net energy expenditure (kcal/session) for each water aerobics class was calculated by first subtracting the resting metabolic rate (1 MET) from the above-calculated MET equivalent of water aerobics

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**Figure 1** — The CosMed K4 b2 portable metabolic system was held by an investigator in a small waterproof Tupperware container during the water aerobic testing session.
exercise. This term was multiplied by individual resting VO₂, individual body mass, divided by 1000, multiplied by 5 (the assumption was made for an energy cost of 5 kcal/L of oxygen), and last multiplied by 50 minutes (length of each water aerobics class). For example, a 93.0-kg individual with a water aerobics MET of 3.9 would have a net metabolic equivalent (exercise – rest) value of 2.9 METs. Multiplying the net metabolic equivalent (2.9) by individual resting VO₂ (3.4 mL · kg⁻¹ · min⁻¹), multiplying by body mass (93.0), dividing by 1000, multiplying by 5, and multiplying by 50 would yield 230 kcal/session.

Statistical Analyses

All analyses were performed using SPSS, version 15.0 (SPSS, Inc, Chicago, IL). Measures of centrality and spread are presented as mean ± SD. Independent t tests were used to compare physical and physiological parameters between genders. The probability of making a type I error was set at P ≤ .05 for all statistical analyses.

Results

Independent t tests revealed no significant differences (P > .05) between genders for all physical characteristics, with the exception of a difference (P = .047) in height. Descriptive statistics of the 14 participants (7 women and 7 men) who completed the study are presented in Table 1. Independent t tests revealed no significant differences (P > .05) between genders for all cardiovascular and metabolic responses, with the exception of a difference (P = .037) in HRmax values. These differences are likely explained by the fact that 2 men were currently prescribed beta-blocker medications. It is well known that beta-blockade therapy reduces HRmax values.18 However, the relationship between %HR and %VO₂max has been shown to be similar between participants prescribed beta-blockade therapy and those not prescribed HR-lowering medications.19 Relative %HR and %VO₂max ranged from 19% to 68% and 25% to 63%, respectively, during the water aerobics exercise. Intensity expressed as METs ranged from 3.0 to 5.8, while total net energy expenditure ranged from 115.0 to 418.0 kcal/session. Cardiovascular and metabolic responses to the water aerobics exercise session are presented in Table 2.

Discussion

The main finding of the current study is that water aerobics exercise in middle-aged and older adults elicits physiological and metabolic responses that fulfill the ACSM exercise-intensity and energy-expenditure guidelines for improving and maintaining cardiorespiratory fitness. Mean exercise intensity was 43.4% of HRmax and 42.2% of VO₂max. Training intensity was 4.3 METs. Total net energy expenditure for the water aerobics exercise session was 249 kcal/session. Collectively, these findings support water aerobics exercise as an ideal alternative exercise modality.

Exercise intensity is arguably the most critical component of the exercise prescription model. Failure to meet minimal threshold values may result in lack of a training effect, while too high an intensity could lead to overtraining and negatively affect adherence to an exercise program.4 Although the ACSM recommends an exercise intensity of 40% to 85% HRR or VO₂max, Swain and Franklin50 concluded that a training intensity exceeding 30% HRR or VO₂max would yield a training effect for individuals with VO₂max values below 40 mL · kg⁻¹ · min⁻¹. All participants in the current study had VO₂max values below this number. It is important that water aerobics exercise exceeded the intensity threshold (30% HRR or VO₂max) for improving cardiorespiratory fitness in all but 1 participant (HRmax = 19% and VO₂max = 25%) in the current study. Moderate exercise intensity in relative terms is defined as 40% to 50% of HRR or VO₂max.5 Participants in the current study self-selected workloads during the water aerobics class that elicited HRmax (43.4%) and VO₂max (42.2%) values that fall within the moderate relative intensity category. In contrast, Campbell et al14 reported mean peak HR values of 72% to 74%, classified as “hard” by ACSM, in older women participating in 40 minutes of shallow-water exercise. Similarly, D’Acquisto et al13 found that during a 40-minute shallow-water exercise session, participants were able to maintain an effort that elicited a “hard” cardiovascular response of 66% to 78% of age-predicted HRmax. Differences in exercise intensity between studies are likely due to methodological differences. For example, Campbell et al14 reported exercise intensity relative to peak HR values obtained during a maximal shallow-water exercise bout, compared with our maximal HR values, which were obtained during maximal treadmill exercise. D’Acquisto et al13 describe relative exercise intensity in terms of age-predicted HRmax, which although acceptable is also associated with a 10- to 15-beats/min standard error of estimation.5

In both the US Surgeon General report on physical activity21 and elsewhere,5 moderate-intensity physical activity in metabolic terms has been classified as 3 to 6 METs. In the current study, the MET response to water aerobics exercise averaged 4.3 and ranged from 3.0 to 5.8. Thus, participants in the present investigation self-selected workloads during the water aerobics class that elicited metabolic responses within the accepted moderate-intensity range. This is an important finding given the fact that moderate-intensity exercise has been widely recommended for health benefits.21 MET values described in the current study compare favorably to those of Campbell et al.14 These authors found MET values ranging from 4.1 to 5.8 during 40 minutes of shallow-water exercise in older women. The MET levels for water aerobics exercise reported in the current study
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ACSM recommendations for daily net energy expenditure. Possible limitations of the current study merit discussion. Although data collection with the portable metabolic analyzer was preferable for collecting valid and reliable metabolic data, the equipment design posed a limitation to participant range of movement due to the short length of the sampling line (~60 cm). Consequently, several exercises were modified to allow for participation in the entire class. Based on observation, the modifications elicited similar to slightly lower physiological responses than the regular movements. Therefore, it is possible that cardiovascular and metabolic data in the current study are an underestimation of values to be expected in real-world settings. Another possible limitation is the relatively short resting period used for collecting resting HR and VO₂. However, unpublished pilot-testing data from our laboratory found no significant differences ($P > .05$) between resting HR and VO₂ values obtained after 5 and 30 minutes of rest. Furthermore, resting values obtained in the current study are comparable to those reported elsewhere.

**Conclusion**

To our knowledge, this is the first study to investigate the cardiovascular and metabolic responses to water aerobics exercise in middle-aged and older adults while

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**Table 1** Descriptive Characteristics of the Participants, Mean ± SD

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Women (n = 7)</th>
<th>Men (n = 7)</th>
<th>Combined (N = 14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>55.7 ± 7.8</td>
<td>59.1 ± 7.6</td>
<td>57.4 ± 7.6</td>
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<tr>
<td>Height (cm)</td>
<td>167.1 ± 6.1*</td>
<td>175.5 ± 7.4</td>
<td>171.3 ± 7.8</td>
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<tr>
<td>Weight (kg)</td>
<td>87.7 ± 17.9</td>
<td>92.2 ± 9.1</td>
<td>89.9 ± 13.9</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>33.6 ± 5.9</td>
<td>30.1 ± 5.8</td>
<td>31.9 ± 5.9</td>
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<td>RHR (beats/min)</td>
<td>71.4 ± 8.3</td>
<td>65.7 ± 6.9</td>
<td>68.6 ± 7.9</td>
</tr>
<tr>
<td>HRmax (beats/min)</td>
<td>173.0 ± 16.6*</td>
<td>147.7 ± 23.2</td>
<td>160.4 ± 23.4</td>
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<tr>
<td>Resting VO₂ (mL · kg⁻¹ · min⁻¹)</td>
<td>3.35 ± 0.27</td>
<td>3.51 ± 0.21</td>
<td>3.43 ± 0.25</td>
</tr>
<tr>
<td>VO₂max (mL · kg⁻¹ · min⁻¹)</td>
<td>30.6 ± 6.7</td>
<td>31.4 ± 10.1</td>
<td>31.0 ± 8.3</td>
</tr>
</tbody>
</table>

*Gender difference, $P < .05$.

**Table 2** Cardiovascular and Metabolic Responses to Water Aerobics, Mean ± SD

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Women (n = 7)</th>
<th>Men (n = 7)</th>
<th>Combined (N = 14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR (beats/min)</td>
<td>111.0 ± 15.3</td>
<td>104.7 ± 13.5</td>
<td>107.8 ± 14.2</td>
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<td>% HRR</td>
<td>37.9 ± 9.2</td>
<td>48.8 ± 12.8</td>
<td>43.4 ± 12.1</td>
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<tr>
<td>Metabolic equivalents</td>
<td>3.99 ± 0.96</td>
<td>4.53 ± 0.96</td>
<td>4.26 ± 0.96</td>
</tr>
<tr>
<td>% VO₂R</td>
<td>38.4 ± 7.3</td>
<td>46.0 ± 11.2</td>
<td>42.2 ± 9.9</td>
</tr>
<tr>
<td>Energy cost (kcal/session)</td>
<td>220.7 ± 83.1</td>
<td>277.4 ± 102.8</td>
<td>249.1 ± 94.5</td>
</tr>
</tbody>
</table>

Abbreviations: RHR, heart rate at rest; HRmax, maximal heart rate; VO₂, metabolic rate; VO₂max, maximal oxygen uptake.

and by Campbell et al are comparable to more traditional land-based aerobic and resistance-training exercise values. Treadmill and overground walking at 5.0 km/h is an equivalent moderate-intensity physical activity at 3.3 METs. Likewise, an 80-kg individual cycling between 50 and 100 W will elicit an MET value ranging from 4.0 to 6.0. Phillips and Zuuraitis reported that resistance training is an alternative form of moderate-intensity physical activity yielding mean MET values of 3.9 and 4.2 in men and women, respectively.

Scientific research has demonstrated that there is a dose-response relationship between exercise and multiple health outcomes, including cardiorespiratory fitness, risk of coronary artery disease and all-cause mortality, obesity, dyslipidemia, type II diabetes, and colon cancer. Based on these dose-response relationships, both the ACSM and the US Surgeon General have noted that the health benefits of a program are associated with the total weekly energy expenditure. Gross (total) energy expenditure includes both the resting metabolic rate and the energy expenditure attributable to the exercise itself (net caloric expenditure). To improve and maintain cardiorespiratory fitness, the ACSM has recommended a target energy expenditure of 150 to 400 net kcal/d. Results from the current study indicated that participation in a 50-minute water aerobics class at self-selected intensity yielded a mean net energy expenditure of 249 kcal/session. These values are sufficient to fulfill the ACSM recommendations for daily net energy expenditure.
employing a portable metabolic analyzer. Findings from the current study support water aerobics as a feasible alternative to land-based exercise for middle-aged and older adults to fulfill the ACSM guidelines for improving and maintaining cardiorespiratory fitness. This is critical, as low cardiorespiratory fitness may contribute to premature mortality in middle-aged and older adults. Moreover, decreased cardiorespiratory fitness contributes to a reduction in physiological functional capacity and eventually can result in loss of independence. Overall, these findings are important for fitness instructors, physical therapists, and others who design exercise programs for adult populations.

References