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

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Running Head: Water Aerobics Exercise
Abstract

Background: The purpose of this study was (a) to assess the cardiovascular and metabolic responses to water aerobic exercise and (b) 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, height, weight, body fat percentage, and maximal oxygen uptake (VO₂max): = 57.4 ± 7.6 years, 171.3 ± 7.8 cm, 89.9 ± 13.9 kg, 32.5 ± 5.8 %, and 31.0 ± 8.3 mL/kg/min, respectively) completed a maximal treadmill exercise test and 50-min water aerobics session. Cardiovascular and metabolic data were collected via a portable calorimetric measurement system. Results: Mean exercise intensity was 43.4% and 42.2% of heart rate reserve (HRR) and maximal oxygen uptake reserve (VO₂R), respectively. Training intensity in metabolic equivalents (METS) 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.$^1$ Studies have consistently demonstrated an inverse relationship between VO$_{2\text{max}}$ values and risk of cardiovascular disease and all-cause mortality.$^2$-$^3$ In fact, it has recently been suggested that cardiorespiratory fitness should be employed as the ultimate marker for risk stratification and health outcomes.$^4$

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.$^5$ The American College of Sports Medicine (ACSM) currently recommends 20-60 minutes of aerobic exercise 3-5 days/week at an intensity of 64/70-94% of heart rate maximum (HR$_{\text{max}}$), 40/50-85% of heart rate reserve (HRR) or oxygen uptake reserve (VO$_{2\text{R}}$), and 12-16 rating of perceived exertion (RPE). Additionally, the ACSM has recommended a target energy expenditure of 150 to 400 net kilocalories per day (kcal/day). 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.$^6$ Although there is a considerable body of literature.$^7$
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 two studies that have dealt with the physiological responses to water aerobics exercise in middle-aged and older adults. In 2000, D’Acquisto, D’Acquisto, & Renne investigated the metabolic and cardiovascular demands of shallow water activity in 60 to 80 year old females. It was reported that 40-min of shallow water exercise elicited mean HRmax responses of 66-78%, which fulfills the ACSM intensity guideline for improving and maintaining cardiorespiratory fitness. Campbell and colleagues compared the physiological and metabolic demands of 40-min shallow water exercise in young and older women. For the older women, cardiovascular demands averaged 70-75% HRmax, while the metabolic demands equaled 4-6 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 HRmax was estimated, not actually measured, and there were only limited samples of expired gas collected for determining the metabolic demands of water exercise. 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 a 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 purpose of this study was (a) to assess the cardiovascular and metabolic responses to water aerobic exercise and (b) to
determine if water aerobics exercise meets the ACSM guidelines for improving and maintaining cardiorespiratory fitness. It was hypothesized that water aerobics will 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. Prior to participation in the community fitness program, participants were risk stratified according to the criteria defined by the ACSM. Those participants 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. Prior to 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 non-consecutive testing days between 6:00-8:00 am. Day 1 consisted of anthropometric measures and 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 abstain from alcohol and caffeine consumption 24 hours prior to each testing session. Participants were also
encouraged to consume a light breakfast prior to 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. 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 (three-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. 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 opto-electrical reader and was 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 maximal oxygen uptake. During the water aerobics exercise session, the portable system was hand held by an investigator in a small water proof tubberware container (Figure 1). Calibration of the CosMed system was completed prior to 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-min 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$_2$) 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 measuring resting expired gases for 2 min, 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 min 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 maximal oxygen consumption (VO$_2$max) was two out of three of the following: (1) a plateau ($\Delta$VO$_2$ $\leq$ 150 mL/min) in VO$_2$ with increases in workload, (2) maximal respiratory exchange ratio (RER) $\geq$ 1.1, and (3) maximal HR within 15 beats/min of the age-predicted maximum (220 – age). VO$_2$max was defined as the highest VO$_2$ obtained over any continuous 30-sec time period, provided two out of the three aforementioned VO$_2$max criteria were attained. Continuous HR measurements were obtained using a Polar F1 heart rate monitor (Polar Electro Inc., Woodbury, NY) that was interfaced with the CosMed system.

**Water aerobics exercise test**

Participants engaged in a 50-min water aerobics class performed in chest-deep water. Participants were instructed to arrive 10 min prior to the start of the 6:10am or 7:10am class
for a series of pre-testing measures, including attachment of the heart rate 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, participants 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-min warm-up consisting of light intensity jogging and other repetitive total body movements and static stretching. The warm-up was followed by a 25-min cardio workout consisting of 20-30 sec bouts of various aerobic movements. Abdominal exercises were performed for 5-min after the cardio portion of the class. Participants then complete a 5-min upper-body workout using resistance bands. The class concluded with a 5-min 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 heart rate reserve (HRR) was determined as the difference between resting and HRmax values. Likewise, individual oxygen uptake reserve (VO₂R) was determined by the difference between resting and maximum VO₂ values. The metabolic equivalent (MET) for water aerobic 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 aerobic class was calculated by first subtracting the resting metabolic rate (1 MET) from the above-calculated MET equivalent of water aerobic 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-min (length of each water aerobic class). For example, a 93.0-kg individual with a water aerobic metabolic equivalent of 3.9 METs would have a net metabolic equivalent (exercise – rest) value of 2.9 METs. Multiplying the net metabolic equivalent (2.9) by individual resting VO\(_2\) (3.4 mL/kg/min), 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 \(p \leq .05\) 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 fourteen 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 two men were currently prescribed beta-blocker medications. It is well known that beta-blockade therapy reduces HRmax values.\(^{18}\) However, the relationship between %HRR and %VO\(_2\)R has been shown to be similar between those participants prescribed beta-blockade therapy compared to those not prescribed HR-lowering medications.\(^{19}\) Relative percent HRR and VO\(_2\)R ranged
from 19% to 68% and 25% to 63%, respectively during water aerobic exercise. Intensity expressed as MET values 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 aerobic exercise session are presented in Table 2.

*Insert Table 1 approximately here*

*Insert Table 2 approximately here*

**Discussion**

The main finding of the present study is that water aerobic 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% and 42.2% of heart rate reserve (HRR) and maximal oxygen uptake reserve (VO$_2$R), respectively. Training intensity in metabolic equivalents (METS) was 4.3. Total net energy expenditure for the water aerobics exercise session was 249 kcal/session. Collectively, these findings support water aerobics exercise as 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 of an intensity could lead to over-training and negatively impact adherence to an exercise program.$^4$ Although the ACSM recommends an exercise intensity of 40-85% HRR or VO$_2$R, Swain and Franklin$^{20}$ concluded that a training intensity exceeding 30% HRR or VO$_2$R would yield a training effect for individuals with VO$_2$max values below 40 mL/kg/min. All participants in the present study had VO$_2$max values below this number. Importantly,
water aerobics exercise exceeded the intensity threshold (30% HRR or VO₂R) for improving cardiorespiratory fitness in all but one participant (HRR = 19% and VO₂R = 25%) in the present study. Moderate exercise intensity in relative terms is defined as 40-59% of HRR or VO₂R. Participants in the present study self-selected workloads during the water aerobics class that elicited HRR (43.4%) and VO₂R (42.2%) values that fall within the moderate relative intensity category. In contrast, Campbell et al. reported mean peak HR values of 72% to 74%, classified as “hard” by ACSM, in older women participating in 40-min of shallow water exercise. Similarly, D’Acquisto et al. found that during a 40-min 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 al. reported exercise intensity relative to peak HR values obtained during a maximal shallow water exercise bout compared to our maximal HR values, which were obtained during maximal treadmill exercise. D’Acquisto et al. describe relative exercise intensity in terms of age-predicted HRmax, which although acceptable, is also associated with a 10-15 beat per minute standard error of estimation.

In both the U.S. Surgeon General report on physical activity and elsewhere, moderate-intensity physical activity in metabolic terms has been classified as 3 to 6 METS. In the present study, the MET response to water aerobic exercise averaged 4.3 and ranged from 3.0 to 5.8. Thus, participants in the present investigation self-selected workloads during the water aerobic 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. MET values described in the present study
compare favorably to those of Campbell et al.\textsuperscript{14}. These authors found MET values ranged from 4.1 to 5.8 during 40-min of shallow water exercise in older women. The MET levels for water aerobic exercise reported in the present study and by Campbell and colleagues\textsuperscript{14} are comparable to more traditional land-based aerobic and resistance training exercise values. Treadmill and over ground walking at 5.0 kilometers per hour is an equivalent moderate-intensity physical activity at 3.3 METS. Likewise, an 80-kg individual cycling between 50 and 100 Watts will elicit a MET value ranging from 4.0 to 6.0 METS.\textsuperscript{5} Philips & Ziuraitis\textsuperscript{22} 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 (CAD) and all-cause mortality, obesity, dyslipidemia, type II diabetes, and colon cancer.\textsuperscript{23} Based on these dose-response relationships, both the ACSM\textsuperscript{5} and U.S. Surgeon General\textsuperscript{21} 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). For the improvement and maintenance of cardiorespiratory fitness, the ACSM has recommended a target energy expenditure of 150 to 400 net kilocalories per day (kcal/day). Results from the present study indicated that participation in a 50-min water aerobic 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.

Possible limitations to the present 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 compared to the regular movements. Therefore, the possibility exists that cardiovascular and metabolic data in the present 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 VO$_2$. However, unpublished pilot testing data from our laboratory found no significant differences ($p > .05$) between resting HR and VO$_2$ values obtained following 5- and 30-min of rest. Furthermore, resting values obtained in the present study are comparable to those reported elsewhere.$^{22}$

**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 employing a portable metabolic analyzer. Findings from the present study support water aerobics as a feasible alternative to land-based exercise for middle-aged and older adults that 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.$^{24}$ Moreover, decreased cardiorespiratory fitness contributes to a reduction in physiological functional capacity and eventually can result in loss of independence.$^{25-26}$ Overall, these findings are important for fitness instructors, physical therapists, and others who design exercise programs for adult populations.
References


Table 1  Descriptive characteristics of the participants

<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 (years)</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>
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<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>HR max (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>Rest VO₂ (mL/kg/min)</td>
<td>3.35 ± 0.27</td>
<td>3.51 ± 0.21</td>
<td>3.43 ± 0.25</td>
</tr>
<tr>
<td>VO₂ max (mL/kg/min)</td>
<td>30.6 ± 6.7</td>
<td>31.4 ± 10.1</td>
<td>31.0 ± 8.3</td>
</tr>
</tbody>
</table>

Values are mean ± SD. (RHR, heart rate at rest; HR max, Rest VO₂, resting metabolic rate; maximal heart rate; VO₂ max, maximal oxygen uptake); *denotes gender difference, p < .05.
### Table 2  Cardiovascular and metabolic responses to water aerobics

<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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<td>Metabolic equivalents (METS)</td>
<td>3.99 ± 0.96</td>
<td>4.53 ± 0.96</td>
<td>4.26 ± 0.96</td>
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<tr>
<td>% VO₂R</td>
<td>38.4 ± 7.3</td>
<td>46.0 ± 11.2</td>
<td>42.2 ± 9.9</td>
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<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>

Values are mean ± SD. (HR, heart rate; HRR, heart rate reserve; VO₂R oxygen uptake reserve).
Figure 1 – The CosMed K4 b2 portable metabolic system was hand held by an investigator in a small water proof tubberware container during the water aerobic testing session.