Title: Comparing Energy Expenditure During Land and Shallow Water Walking in Overweight and Obese Females

Statement of the Problem
The prevalence of overweight and obesity in the United States has reached epidemic levels with approximately 69% of adults classified as overweight (Body Mass Index (BMI) ≥ 25.0 kg/m²) and more than one third (36%) of Americans classified as obese (BMI ≥ 30.0 kg/m²).1 Overweight and obesity are associated with higher rates of all-cause mortality2, as well as an increased risk for several chronic diseases including cardiovascular disease, type II diabetes mellitus, certain forms of cancer, and osteoarthritis.3 As a major contributor to preventive death in the United States today, overweight and obesity pose a major public health challenge,4 and has been extensively researched over the past few decades. One such area of research is the contribution of physical activity to the prevention and treatment of obesity.

As previously stated, reduction in body weight is of great importance for overweight and obese individuals through the increase in physical activity. One particular mode of physical activity that is currently growing in popularity is aquatic exercise (AE), utilizing land-based physical activity adapted to a water medium.5 One particular aspect of AE of recent interest is shallow water walking, as it is an easy aerobic activity that does not require prior swimming skill.6 Although there is sufficient evidence to support the metabolic, cardiovascular, and psychological benefits of AE,5,7-19 little research has been done examining the energy cost of AE. It is hypothesized that water walking as a part of an AE program may be considered an effective alternative to land-based exercise as well as provide unique benefits that land-based exercise does not for individuals with a body weight problem,20 although an under-studied and currently limited area of research. In conclusion, although AE may serve as an alternative mode of exercise, the relative energy cost is currently unknown compared to the land alternative in overweight and obese individuals.

Specific Aim I: To compare the energy expenditure (kcal·min⁻¹) of a bout shallow water walking at a self-selected pace to a bout of land walking at a matched heart rate response and to a bout of land walking at a self-selected pace in overweight and obese women.

Specific Aim II: To compare the perceived exertion (RPE) during a bout of shallow water walking at a self-selected pace to a bout of land walking at a matched heart rate response and to a bout of land walking at a self-selected pace in overweight and obese women.

Theoretical/Conceptual Framework
Although the minimal existing intervention data is promising, showing equal reductions in body weight and body fat with aquatic compared to land-based forms of exercise,21,22 the acute physiological responses to water-based exercise are not well understood. Research has examined the energy cost of many land-based forms of exercise23 however, solid evidence regarding energy expenditure does not currently exist for AE. Some research has hypothesized that effects of water buoyancy, resulting in up to 90% reduction in body weight, as well as resistance due to the exponentially higher density of water than air make it possible to expend high levels of energy while at the same time reducing strain and impact force on lower extremity joints.20,24 Furthermore, a higher percentage of body fat will potentially increase buoyancy during water immersion resulting in a greater relative energy cost at a given workload due to the additional forces and movements required to counteract the effects of added buoyancy while immersed.25
Thus the water environment could potentially allow for high levels of energy expenditure relative to comparable land-based exercise, although this hypothesis has not been confirmed. Therefore, knowledge of the expected physiological responses and estimated energy cost of a given exercise is necessary for the clinician to make decisions on safe and effective exercise programs.24,26

One potential benefit of water-based exercise over land-based exercise is the partially weight-bearing mode. The use of regular exercise in the treatment of these patients is thus strongly influenced by their ability to exercise. However, some research states that these patients may not be able to tolerate weight-bearing aerobic activities of sufficient duration due to the strain excess body weight puts on their joints.27 Obese individuals are typically prescribed moderate intensity land-based activities due to its practical nature and convenience.28,29 However, severely obese individuals, particularly those with a BMI of 40 kg/m² and above, may have difficulty performing generally prescribed physical activity. Prolonged weight-bearing exercises can even cause musculoskeletal problems in this population with no previous history of joint disease,30,31 potentially leading to a discontinuation of their programs. Furthermore, obesity is associated with musculoskeletal pain, as well as with osteoarthritis of the knee and hip,32-34 with every 5kg of weight gain increasing the risk of knee arthritis by 35%.35 Consequently, there is mounting evidence to support that obese individuals have a reduced exercise tolerance, especially when BMI is greater than 40 kg/m².36 Furthermore, the net metabolic rate of walking in overweight and obese subjects is approximately 10-45% greater than in normal weight individuals,37,38 placing them at a greater percentage of their maximum aerobic capacity, making it more difficult to maintain recommended exercise durations. Therefore, the standard prescription of brisk walking for long durations and high frequency, even at a lower intensity (30-50% VO₂max), may be perceived as too strenuous.36

Thus, obese individuals may find water to be a desirable environment for exercise due to the cushioning effect of exercise in water potentially preventing injuries caused by excessive strain on the joints of the lower extremities and may be perceived as less strenuous.21,23,24,39 For these reasons, water walking as a part of an AE program may be considered an effective alternative to land-based exercise as well as provide unique benefits that land-based exercise does not for individuals with a body weight problem,20 although an under-studied and currently limited area of research. In conclusion, although AE may serve as an alternative mode of exercise, the relative energy cost is currently unknown compared to the land alternative in overweight and obese individuals.

**Methods, Design and Procedures**

**Subjects:** A total of 19 apparently overweight and obese (BMI 25-44.9 kg/m²), but otherwise healthy women between the ages of 18-55 will be recruited to participate in this study. Subjects will be excluded if height < 160cm) or > 173cm; previous diagnosis of conditions requiring additional medical clearance; presence of a medical condition that may limit one’s ability to walk for exercise; currently taking medications affecting heart rate, pregnancy; or discomfort exercising in shallow water.

**Experimental Design:** The proposed study will utilize a crossover design. Eligible subjects will report for three experimental trials following the initial orientation and assessment session, separated by at least 48 hours, but no more than 7 days, and will take place ± 1 hour. The experimental trials will be partially counterbalanced to reduce testing bias. The only condition of
the counterbalancing requires the shallow water-walking bout to precede the matched heart rate response bout due to the study protocol, with the other condition being random.

1. Orientation and Assessment Session- The Principle Investigator will review the study protocol and allow individuals an opportunity to answer any questions before signing an informed consent document. Subjects will then complete a Physical Activity Readiness Questionnaire (PAR-Q) to ensure that participation in exercise is not contraindicated. The assessment portion will consist of collecting Height, weight, BMI, body composition (% fat), waist circumference, hip circumference, thigh circumference, leg length, physical activity level, previous shallow water and treadmill exercise experience. Subjects will then undergo familiarization trials to treadmill walking and shallow water walking technique and equipment, lasting ~10 minutes.

2. Shallow Water Walking Exercise Trial (WE)- Subjects will complete a 10-minute WE at a self-selected pace. Subjects will be instructed to walk at a “comfortable brisk walking pace that can be sustained for 10 minutes.” During the initial 5 minutes, the subjects will be prompted at 30-second intervals to adjust their pace (faster or slower) if they felt it necessary to do so in order to complete the entire 10-minute experimental session. At the 5-minute mark, subjects will be instructed to maintain their current pace throughout the remainder of the exercise session. Following the 10-minute exercise bout, the subject will be asked to rate their perceived exertion using the Borg 15-category scale. All WE bouts will be recorded using an underwater camera. Filming each session allows the researcher to analyze the cadence (steps/min), speed (m/s), and distance completed (m) post hoc for further descriptive purposes.

3. Matched Heart-rate Response Land Exercise Trial- To determine the target HR for this trial, HR obtained during the last 5 minutes of the shallow water trial will be averaged. The subject will be fitted with the equipment and instructed to sit quietly in a chair for 5 minutes to allow for acclimatization to the equipment. To begin the 10-minute trial, the treadmill will be initially set at a speed of 1.0 mph and 0% incline and the subject will step on to the treadmill and will be instructed to begin walking. Every 30 seconds, the speed of the treadmill will be increased by 0.5 mph until the subject achieves the target HR ± 5 bmp. After the initial 5 minutes, adjustments will be made to the speed (± 0.1 mph) at 1-minute intervals as needed to maintain the appropriate heart rate range throughout the test.

4. Self-Selected Pace Land Exercise Trial- Prior to testing, the subject will be fitted with the equipment and will sit quietly in a chair for 5 minutes to allow for acclimatization to the equipment. To begin the 10-minute trial, the treadmill will be initially set at a speed of 1.0 mph and 0% incline and the subject will step on to the treadmill and will be instructed to begin walking. During the initial 5 minutes, the subject will give a signal to the research technician at 30 second intervals to increase, decrease, or maintain the speed of the treadmill to elicit their perceived comfortable self-selected brisk walking pace. These adjustments will be made at 0.5 mph increments. The speed of the treadmill achieved at 5 minutes will be maintained through the remainder of the experimental session. Following the 10-minute exercise bout, the subject will be asked to rate their perceived exertion using the Borg 15-category scale. To allow the subject to achieve steady state, only the final 5-minutes of the test will be used for data analysis.

Instrumentation

Indirect Calorimetry: Oxygen consumption (VO₂), carbon dioxide production (VCO₂), respiratory exchange ratio (RER) and pulmonary ventilation (Ve) will be measured during the WE and land trials using the portable Cosmed K4b² metabolic unit and Aquatrainer mask.
attachment (Chicago, IL), allowing for an in-pool measure of VO2. The validity and reliability of device have been previously established for land and water use.41 The Aquatrainer attachment will be used during the WE trial and a facemask attachment will be used during the land trials. The primary outcome is energy expenditure per minute (kcal·min⁻¹) of the last 5 minutes of each trial, which will be determined from VO2 (l·min⁻¹) using the non-protein caloric equivalent (RER) to adjust for energy substrate utilization.

Heart Rate Monitor: Heart rate (not heart rhythm) will be monitored continuously using a Polar heart rate monitor (Port Washington, NY) during all trials.

Ratings of Perceived Exertion (RPE): The Borg 15-category rating scale of perceived exertion will be used to measure overall effort and perceived exertion during all trials. Prior to testing, the scale will be described to the subject to ensure their understanding using a standardized script.

Data Analysis
The sample size calculation was determined using G*Power. Based on an article by Hill and colleagues it was determined that 50 kcal/day could offset weight gain in about 90% of the population.42 Therefore, 50 kcal/h, or 0.83 kcal/min was determined as a clinically meaningful level of energy expenditure. The results of Alkurdi et al. showed an average standard deviation for energy expenditure at the proposed water depth across conditions of 1 kcal/min, resulting in an effect size of 0.83.43 Furthermore, the type I error rate was set at $p = 0.0167$ using the Bonferroni correction based on the multiple comparison post hoc analyses if a main effect is detected. Therefore, it was determined that to detect an effect size of 0.83, with power set at $1-\beta = 0.8$, and $p = 0.0167$, that 19 subjects would be required. Descriptive analyses will be performed for height, weight, BMI, waist circumference, leg length, and % body fat. To examine Specific Aim 1 and 2, separate one-way repeated measures analysis of variance (ANOVA) will be performed for the energy expenditure during the last 5 minutes of the exercise trials, and RPE across exercise trials. When appropriate, post-hoc comparisons will be made using the Bonferroni adjustment to determine which conditions were significantly different.

Contribution to Knowledge of Disciplines that Inform School of Education Programs
Although aquatic exercise may be considered a desirable alternative exercise modality for overweight and obese individuals, the caloric cost of the activity should be considered and difficulties may arise if the prescribed relative energy cost is based on land based activities. Researchers have stated that the use of land-based prescriptive norms would underestimate the metabolic cost in water.45 This study aims to address the gaps in the literature regarding the energy cost of a bout of water walking compared to a bout of land walking in a sample of overweight and obese women. It is hypothesized that the energy expenditure will be higher during a bout of shallow water walking than during a bout of land walking, as well as elicit lower levels of perceived exertion. A similar or significantly higher energy expenditure and similar or lower levels of perceived exertion during a matched bout of water exercise would warrant further research of the chronic effects of aquatic based exercise as an alternative mode of physical activity in overweight and obese individuals.
**Budget and Justification**

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<tr>
<th>ITEM</th>
<th>COST</th>
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<tr>
<td>1. Subject Payment, @ $75 per subject (19 subjects)</td>
<td>$1425.00</td>
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<td>Recruitment of 19 females aged 18-55 years undergoing three experimental sessions on separate occasions will be greatly enhanced if subjects are paid a modest stipend for their participation. Subjects will be paid $25 per exercise session for a total estimated cost of $75 per subject.</td>
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<td>2. Printing</td>
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<td>Copies will be made for all study materials including recruitment letters, fliers, phone screenings, and data collection sheets @ $0.04 per copy. The estimated number of copies needed is 600 with a total estimated cost of $24.00.</td>
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<tr>
<td>3. Registry Mailings</td>
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<td>Mailings will go out to individuals meeting the criteria in the ONRC registry. The estimated number of mailings that will be sent is 75 @ $0.46 per mailing cost and the cost of envelopes @ $4.59 for a box of 25. The total estimated cost is $48.27.</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$1497.27</strong></td>
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References


15. Sanders ME. *Selected Physiological Responses to a Water Exercise Program Called Wave Aerobics*, University of Nevada, Reno; 1993.


