

11-1-2014

Underwater Treadmill Training, Glycemic Control, and Health-Related Fitness in Adults with Type 2 Diabetes

Ryan T. Conners

Middle Tennessee State University, Ryan.Conners@uah.edu

Don W. Morgan

Middle Tennessee State University

Dana K. Fuller

Middle Tennessee State University

Jennifer L. Caputo

Middle Tennessee State University

Follow this and additional works at: <https://scholarworks.bgsu.edu/ijare>

Recommended Citation

Conners, Ryan T.; Morgan, Don W.; Fuller, Dana K.; and Caputo, Jennifer L. (2014) "Underwater Treadmill Training, Glycemic Control, and Health-Related Fitness in Adults with Type 2 Diabetes," *International Journal of Aquatic Research and Education*: Vol. 8 : No. 4 , Article 8.

DOI: <https://doi.org/10.25035/ijare.08.04.08>

Available at: <https://scholarworks.bgsu.edu/ijare/vol8/iss4/8>

This Research Article is brought to you for free and open access by the Journals at ScholarWorks@BGSU. It has been accepted for inclusion in International Journal of Aquatic Research and Education by an authorized editor of ScholarWorks@BGSU.

Underwater Treadmill Training, Glycemic Control, and Health-Related Fitness in Adults With Type 2 Diabetes

**Ryan T. Conners, Don W. Morgan, Dana K. Fuller,
and Jennifer L. Caputo**
Middle Tennessee State University

The purpose of this study was to document the influence of underwater treadmill training (UTT) on glycemic control and health-related fitness in middle-aged adults with type 2 diabetes. Pre- and posttraining measurements of glycosylated hemoglobin (HbA1c), body mass (BM), percent body fat (%BF), waist circumference (WC), resting heart rate (RHR), estimated aerobic capacity (VO_{2max}), and concentric peak quadriceps and hamstrings torque were obtained on 7 adults (mean age = 55.3 ± 7.7 years) who participated in 8 weeks (3d-wk-1) of UTT. Walking speed was initially set at a relative intensity of 40–50% of heart rate reserve (HRR) and gradually raised to 50–70% HRR by week 8. Walking duration of each session was increased from 30 to 60 minutes during the study. Following UTT, reductions ($p < .05$) occurred in HbA1c, BM, %BF, and WC. In addition, RHR was lower, estimated VO_{2max} was higher, and peak hamstrings torque at $30^\circ\cdot\text{sec}^{-1}$, $60^\circ\cdot\text{sec}^{-1}$, and $90^\circ\cdot\text{sec}^{-1}$ and peak quadriceps torque at $30^\circ\cdot\text{sec}^{-1}$ and $60^\circ\cdot\text{sec}^{-1}$ were greater after UTT. Our preliminary findings suggest that UTT is a safe and effective modality in controlling blood glucose levels and improving body composition, cardiorespiratory function, and leg strength in middle-aged adults with type 2 diabetes.

Keywords: aquatic exercise; aquatic therapy; underwater treadmill training

Type 2 diabetes is a chronic disease that can lead to decreased insulin sensitivity and a reduced ability to maintain glucose control. A common diagnostic measure of diabetes is glycosylated hemoglobin (HbA1c), which reflects mean blood glucose levels over a 1- to 3-month period (Bennett, Guo, & Dharmage, 2007; Marcus et al., 2008). In adults, an HbA1c value lower than 5.7% is considered normal, whereas levels between 5.7–6.49% indicate prediabetes, and a value of 6.5% or higher is reflective of diabetes (Gebel, 2013). A strong correlation exists among

Ryan Conners, Don Morgan, and Jennifer Caputo are with the Department of Health and Human Performance and Dana Fuller is with the Department of Psychology, all at Middle Tennessee State University in Murfreesboro, TN. Address author correspondence to Ryan Conners at Ryan.Conners@mtsu.edu.

HbA1c levels, microvascular complications, reduced glycemic control, glycation of proteins, and complications associated with type 2 diabetes (Kharroubi, Darwish, Al-Halaweh, & Khammash, 2014).

Given the health benefits of endurance exercise in reducing body weight and body fat, normalizing blood lipid profiles, and improving whole-body insulin sensitivity, lifestyle intervention programs for persons with type 2 diabetes typically incorporate aerobic training (Praet & van Loon, 2007). Factors such as muscle weakness and diminished exercise tolerance, however, can lessen participation in and adherence to aerobic activities among individuals with type 2 diabetes (Sayer et al., 2005). Interventions featuring resistance exercise also have been shown to lower HbA1c, enhance insulin sensitivity, and increase skeletal muscle mass, thereby improving glucose-disposal capacity (American College of Sports Medicine [ACSM], 2014; Dunstan et al., 2002) and enabling activities of daily living to be accomplished with less relative physical strain (Praet & van Loon, 2007). While compelling evidence exists for persons with type 2 diabetes to regularly engage in cardiorespiratory and musculoskeletal exercise, participation in a comprehensive, therapeutically-based regimen consisting of moderate-to vigorous-intensity aerobic and resistance-based activities can be difficult to sustain (Marcus et al., 2008; Praet & van Loon, 2007). Performing these commonly prescribed exercise programs could potentially lead to overuse injuries, especially among individuals who are relatively sedentary, overweight, display low exercise capacity, or experience musculoskeletal pain while engaging in traditional forms of aerobic exercise and strength training (Marcus et al., 2008). Hence, a need exists to develop and test new strategies to optimize health-producing benefits of physical activity which integrate endurance and resistance training, while enhancing program compliance and minimizing health complications (Praet & van Loon, 2007).

An innovative exercise program which has remained largely unexamined, but holds great promise in improving the metabolic health, aerobic fitness, and physical function of persons with type 2 diabetes, is underwater treadmill training (UTT). The use of a treadmill submerged in a self-contained tank allows for the precise control of walking speed, water depth, and water temperature, a trio of variables which can markedly influence aerobic and strength training responses. The partial support supplied by the buoyant effect of water also creates a more comfortable and realistic unloading of body weight than that provided by typical harness unweighting systems and can serve as an effective alternative to land-based walking programs in adults who display mobility and balance problems and lower-limb joint and muscle weakness (Bocalini, Serra, Murad, & Levy, 2008). Other advantages of walking on an underwater treadmill include generation of muscle activity and gait patterns similar to those recorded during land walking, enhanced cardiovascular function due to the hydrostatic pressure of water, and increased leg strength caused by over-coming water resistance and turbulence (Giaquinto, Ciotola, & Margutti, 2007).

Against this backdrop, we conducted an exploratory study to quantify the effects of UTT on glycemic control and selected components of health-related fitness in middle-aged men and women with type 2 diabetes. Specifically, it was hypothesized that an 8-week program of UTT would result in better control of blood glucose levels and improvements in body composition, cardiorespiratory function, and leg strength.

Method

Participants

Adults (2 males, 5 females; mean age = 55.3 ± 7.7 years) with type 2 diabetes volunteered to participate in this study. Participant characteristics are displayed in Table 1. Inclusion criteria for participants included confirmation of diabetes (fasting plasma glucose value of ≥ 126 mg/dl or current use of diabetes medications) and medical clearance from a personal physician (Castaneda et al., 2002). Eligible participants also refrained from participation in aerobic or resistance training during the 6-month period preceding UTT. Exclusion criteria included occurrence of a myocardial infarction within 6 months before the start of the investigation, recent changes in oral hypoglycemic medication use, and the presence of additional chronic medical conditions (e.g., respiratory disease, heart failure, renal disease, hepatic disease, myopathies, neuropathies) that could hinder full participation in UTT. Written informed consent was obtained from all study participants before data collection.

Outcome Measures

Baselines measures of glycemic control, body composition, cardiorespiratory function, and leg strength were secured one week before the start of UTT. Posttraining measures were obtained within one week following completion of UTT.

Glycemic control. The primary measure for glycemic control was HbA1c, a measure of average blood glucose over the previous 1- to 3-month period (Marcus et al., 2008). A 10-ml venous blood sample was drawn from a forearm vein and analyzed for HbA1c using turbidimetric immunoinhibition. Diabetic medication levels for each participant were recorded by their primary physician and rechecked for maintenance following cessation of UTT.

Anthropometric measures. Body mass (without shoes) was measured to the nearest 0.1 kg using a Seca 869 flat digital scale (Hanover, MD) and height was determined to the nearest 0.25 cm using a Seca 217 stadiometer (Hanover, MD).

Table 1 Participant Characteristics

| Variable | M \pm SD |
|--|-------------|
| Mean age (years) | 55.3 (7.7) |
| Sex (female/male) | 5/2 |
| Height (m) | 1.7 (0.1) |
| Body mass (kg) | 88.2 (14.3) |
| Length of diabetes diagnosis (years) | 5.7 (3.1) |
| Number of current smokers | 0 |
| Percentage taking diabetes medications | 57 (4) |

Note. Values are mean \pm standard deviation.

A trained laboratory technician measured skinfold thickness (in duplicate) at seven upper- and lower-body sites with a Harpenden skinfold caliper (Model 136, West Sussex, UK). Using population-specific equations (Allison et al., 2011), average thicknesses at each anatomical location were used to calculate body fat percentage (%BF) and lean body mass. Duplicate measures of waist circumference (WC), taken as the circumference around the body at the narrowest distance between the last rib and the anterior superior iliac spine, were also obtained using a Gulick tape measure and averaged to derive mean WC. To mitigate the potential influence of nutritional influences on body composition, participants were reminded on a weekly basis to maintain their current dietary patterns.

Cardiorespiratory function. Following 5 min of seated rest in a quiet, dark room, resting heart rate (RHR) was determined from palpation of the radial pulse for 30 s and doubling the number of recorded beats (Allison et al., 2011). Duplicate measures of RHR were obtained within a 5-min period and averaged to derive mean RHR. The rationale for measuring RHR was based on data showing that RHR is lower following endurance training in previously sedentary individuals (Carter & Blaber, 2003).

Maximal aerobic power (VO_{2max}) was estimated using a single-stage, land-based walking treadmill protocol (Ebbeling, Ward, Puleo, Widrick, & Rippe, 1991). Participants wore a Polar heart rate monitor and watch (Model FT1, Lake Success, NY) during testing. The test began with participants walking at 2 mph and 0% grade and speed was increased gradually until a heart rate of 50–70% of estimated maximal heart rate ($220 - \text{age}$) was attained. After completing this 4-min warm-up stage, treadmill grade was increased to 5% and walking speed was maintained for an additional 4 min. Heart rate was recorded at the end of 8 min of exercise (including the warm-up stage) and used, along with sex, age, and treadmill speed, to predict VO_{2max} (Ebbeling et al., 1991).

Leg strength. Concentric peak torque of the dominant leg quadriceps and hamstrings at $30^\circ \cdot \text{sec}^{-1}$, $60^\circ \cdot \text{sec}^{-1}$, and $90^\circ \cdot \text{sec}^{-1}$ was assessed using a Biodex System III dynamometer (Biodex Medical Systems, Shirley, NY). The dominant leg was identified as the leg chosen to kick a ball (Zakas, 2006) and this trio of contraction velocities was chosen to reflect a range of overground walking speeds (Lanshammar & Ribom, 2011). Participants were seated in an upright position and adjustable straps were placed around the upper body and the dominant thigh to isolate the quadriceps and hamstrings and limit the amount of muscle activation in the muscle groups not being evaluated. The main fulcrum of the lever arm of the dynamometer was positioned at the lateral aspect of the knee joint axis.

Range of motion for strength testing was measured from a start position of the knee joint bent at 90° through full extension (0° flexion) and back to 90° of knee flexion. Standardized verbal encouragement was provided to each participant during testing and a total of three accommodation trials preceded quadriceps and hamstrings testing at each contraction velocity. Following the accommodation phase, participants performed three maximum voluntary efforts at each contraction velocity, with 30 s of rest between trials. For each muscle group and velocity condition, the highest torque measure across trials was taken as the peak torque value. Leg strength was expressed as peak torque (ft-lbs), which is considered a representative indicator of both knee flexion and extension strength (Blain et al., 2001).

Protocol

Treadmill accommodation. Prior to UTT, participants completed two pretraining accommodation walking sessions spaced two days apart. The treadmill accommodation sessions occurred in a therapy pool, which contained an underwater treadmill (Ferno, Wilmington, OH) and a control panel from which the treadmill was operated, a water reservoir with a water filtration system, a variable-speed motor, and two large Plexiglas windows which enabled participants to be visually monitored (see Figure 1). Water height was set at 10 cm below the xiphoid process (Alkurdi, Paul, Sadowski, & Dolny, 2010) and maintained during training. For both treadmill accommodation sessions, a Polar heart rate monitor was worn and heart rate was recorded before the session and following the first minute of walking. During each session, participants walked for 5 min at a speed that elicited 20% of HRR [$HRR = ((\text{age-adjusted maximal heart rate} - RHR) \times \% \text{ intensity desired}) + RHR$].

Exercise intervention. Participants completed three UTT sessions per week on alternate days for a total of 8 weeks. Each training session featured three walking bouts separated by at least 5 min of seated rest on a flotation device inside the underwater treadmill unit. Water temperature was maintained between 29–30°C (Bocalini et al., 2008) and exercise heart rate was monitored at the beginning, middle, and conclusion of each exercise bout using a Polar heart rate monitor. Baseline levels of exercise intensity and duration and the systematic progression



Figure 1 — A participant walking on the underwater treadmill.

of these training variables were established based on previous research involving water-based exercise (Jones, Meredith-Jones, & Legge, 2009; Stevens & Morgan, 2010) and exercise guidelines published by the American College of Sports Medicine (ACSM, 2014).

During UTT, walking speed and duration were increased in a structured and gradual manner (see Table 2) and participants were asked to maintain their usual levels of home- and community-based physical activity. Weekly checklists were also completed by participants to record physician visits, acute illnesses, and hypoglycemic events that occurred during the study (Castaneda et al., 2002).

Statistical Analyses

Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) version 19.0. Paired *t* tests were used to compare pre- and post-UTT values for HbA1c, body mass, %BF, WC, RHR, estimated VO_2max , and hamstring and quadriceps peak torque. Statistical significance was established at $p \leq .05$.

Results

Participant Compliance and Exercise-Related Injuries

Compliance with the underwater treadmill training program was 100%, with all participants completing 24 (8 wks \times 3 day-wk⁻¹) UTT sessions. In addition, no exercise-related injuries were reported. One hypoglycemic event occurred after UTT and was treated immediately by having the participant ingest a high-sugar beverage. No hypoglycemic events were recorded at home or in transit from the exercise laboratory.

Glycemic Control and Anthropometric Measures

An average reduction in HbA1c from 6.7 to 6.0% was observed following UTT ($p < .001$). Six of the seven participants reported no change in diabetic medication levels, and the remaining participant reduced medication usage during the study. Relative to anthropometric measures, mean body mass (3.4 kg, $p = < .001$), %BF (3.6%, $p = .001$), and WC (8 cm, $p = .001$) were reduced after UTT, but lean body mass was not significantly altered following training (see Table 3).

Table 2 Weekly Exercise Progression for Underwater Treadmill Training

| Variable | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 |
|--------------------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| Intensity (HRR) | 40–50 | 40–50 | 40–50 | 50–60 | 50–60 | 50–70 | 50–70 | 50–70 |
| Duration (trials \times min) | 3 \times 10 | 3 \times 12 | 3 \times 14 | 3 \times 14 | 3 \times 16 | 3 \times 16 | 3 \times 18 | 3 \times 20 |

Note. W = week; HRR = [(age-adjusted maximal heart rate—resting heart rate) \times % intensity desired] + resting heart rate].

Table 3 Changes in Primary Outcome Variables Following Underwater Treadmill Training

| Variable | Pre-UTT | Post-UTT |
|---|--------------|--------------|
| Glycemic control | | |
| HbA1c (%) | 6.7 ± 2.0 | 6.0 ± 2.0* |
| Anthropometric measures | | |
| Body mass (kg) | 88.2 ± 14.0 | 84.7 ± 4.2* |
| Body fat (%) | 28.3 ± 6.6 | 24.7 ± 5.5* |
| Waist circumference (cm) | 105.0 ± 13.1 | 97.0 ± 10.5* |
| Cardiovascular function | | |
| Resting heart rate (bpm) | 83 ± 14 | 75 ± 13* |
| Estimated VO ₂ max (ml·kg ⁻¹ ·min ⁻¹) | 28.8 ± 3.9 | 31.0 ± 4.0* |
| Leg strength (ft-lbs) | | |
| Hamstrings peak torque @ 30°·sec ⁻¹ | 42.7 ± 12.3 | 53.2 ± 17.0* |
| Hamstrings peak torque @ 60°·sec ⁻¹ | 35.9 ± 10.4 | 47.7 ± 12.0* |
| Hamstrings peak torque @ 90°·sec ⁻¹ | 32.2 ± 10.2 | 42.1 ± 11.4* |
| Quadriceps peak torque @ 30°·sec ⁻¹ | 71.4 ± 23.1 | 76.9 ± 20.2* |
| Quadriceps peak torque @ 60°·sec ⁻¹ | 60.0 ± 21.0 | 67.0 ± 15.2* |
| Quadriceps peak torque @ 90°·sec ⁻¹ | 48.1 ± 19.3 | 56.4 ± 13.3 |

Note. Values are mean ± standard deviation; UTT = underwater treadmill training; * = $p \leq .05$ from pretraining values.

Cardiorespiratory Function and Leg Strength

A mean decrease in RHR of 7 beats per minute (bpm) occurred after UTT ($p = .002$) and estimated VO₂max increased by an average of 2.6 ml·kg⁻¹·min⁻¹ ($p < .001$). With respect to leg strength, an average increase of 5.5 ft-lbs ($p = .027$) and 7.0 ft-lbs ($p = .05$) were observed in quadriceps peak torque measured at 30°·sec⁻¹ and 60°·sec⁻¹, respectively, and a trend ($p = .07$) toward greater peak torque of the quadriceps at 90°·sec⁻¹ (8.3 ft-lbs) was noted. In addition, mean posttraining gains in peak hamstring torque at 30°·sec⁻¹ (10.4 ft-lbs; $p = .007$), 60°·sec⁻¹ (11.8 ft-lbs; $p = .002$), and 90°·sec⁻¹ (9.9 ft-lbs; $p = .01$) were registered after UTT (see Table 3).

Discussion

The focus of this exploratory study was to quantify the impact of UTT on various health and fitness variables that are particularly relevant for adults with type 2 diabetes. Taken together, our findings indicate that for this clinical population, an aquatic treadmill walking program featuring systematic and gradual increases in walking speed and duration resulted in overall improvements in glycemic control, body composition, aerobic fitness, and peak leg torque. Positive changes in each

dependent variable were also exhibited by all study participants, thus highlighting the coherent nature between group and individual responses to UTT.

Patient Compliance and Adverse Events

Despite the crucial role of regular physical activity in the optimal management of diabetes, more than 36% of persons with type 2 diabetes do not engage in regular physical activity and an additional 38% report less than recommended levels of physical activity (American Association of Diabetes Educators, 2012). We speculate that the perfect adherence rate observed during UTT was related to the use of light and moderate exercise intensities and the incremental rise in total exercise volume (i.e., intensity \times duration). Support for this assertion can be found in data revealing high levels of exercise adherence and enjoyment in overweight individuals exercising below vigorous levels (Lind & Ekkekakis, 2005).

No exercise-related injuries were experienced by participants during the 168 training UTT sessions (24 training sessions \times 7 participants) and the single hypoglycemic event which did occur was resolved in a timely and satisfactory manner. In comparison, other studies of land-based treadmill walking and resistance training involving adults with type 2 diabetes have reported a higher number of hypoglycemic events (Castaneda et al., 2002). As previously noted, it is reasonable to suggest that the combination of less-intense workloads and gradual increases in walking duration contributed to the near-absence of negative clinical events in our group of sedentary and relatively unfit participants. It is also possible that the concurrent performance of light-to-moderate aerobic- and resistance-based walking exercise in a weight-supported environment may have led to a reduced incidence of injuries and hypoglycemic episodes compared with studies of persons with type 2 diabetes featuring longer and more-intense exercise programs and separate, land-based aerobic and resistance training sessions (Sigal et al., 2007).

Glycemic Control

Participants in our investigation exhibited a modest degree of initial glycemic control, as demonstrated by a mean HbA1c level of 6.7%. The 0.7% decrease in HbA1c after 8 weeks of UTT is consistent with data showing reductions of 0.55% and 0.59% in HbA1c following 16 weeks of combined aerobic and resistance training performed on land, respectively (Marcus et al., 2008; Tan, Li, & Wang, 2012). Likewise, our findings concur with meta-analyses performed by Umpierre et al. (2011) and Snowling and Hopkins (2006) revealing mean decreases in HbA1c of 0.67% and 0.80%, respectively, when adults with type 2 diabetes performed structured land-based aerobic exercise, resistance exercise, or a combination of both training modes for at least 12 weeks. Expressed as a function of study duration, the magnitude of improvement in HbA1c levels following UTT was more than two times that reported in earlier investigations of middle-aged and older adults with type 2 diabetes who participated in both land-based endurance and resistance training programs (Alkurdi et al., 2010; Jones et al., 2009). Proposed mechanisms underlying the beneficial combined aerobic and resistance training on glycemic control include improved insulin action (Castaneda et al., 2002), enhanced glucose uptake due to up-regulation of mitochondrial proteins (Menshikova et al., 2006), increased glucose-4 transporter protein content and glycogen synthase activity

leading to conversion of plasma glucose into glycogen (Christ-Roberts et al., 2003), and an elevation in metabolic rate and glucose uptake resulting from an increase in contractile proteins (Eriksson et al., 1997).

While few data are available concerning the effects of aquatic walking programs in adults with type 2 diabetes, results from our study are in agreement with findings of Jones et al. (2009) showing that water-based exercise incorporating deep water running and resistance exercise is effective in improving glucose and insulin response in overweight women with impaired glucose tolerance. Interestingly, the positive changes in glycemic control observed in our participants were independent of diabetic medication use, which either remained unchanged or decreased during the study, and the degree of reduction in HbA1c (0.7%) was comparable to that reported following long-term diabetic pharmacological interventions (Allison et al., 2011) in persons with type 2 diabetes (0.6–0.8%). From a clinical perspective, findings from the current project suggest that engaging in UTT may reduce the need for oral hypoglycemic agents in persons with type 2 diabetes and provide health benefits for individuals who are not fully compliant in taking diabetic medications.

Anthropometric Measures

Body mass, %BF, and WC were lower after the UTT program. The average reduction in body mass of 3.5 kg is generally consistent with recommended weekly weight-loss standards for adults (0.5–0.9 kg·wk⁻¹) established by the American College of Sports Medicine (ACSM, 2014). The decrease in body mass noted in our investigation may have been associated with the elevated aerobic demand of walking in an aquatic environment compared with walking on land. Related to this point, it has been shown that walking on a submerged treadmill results in a significantly higher aerobic demand compared with walking on a land-based treadmill (Alkurdi et al., 2010). The degree of body mass loss recorded among our participants, which was markedly greater than the mean decrease of 0.7 kg observed in middle-aged obese adults who performed 12 weeks of underwater treadmill walking, may reflect the interactive effect of walking speed and water height on overall exercise intensity (Greene et al., 2009). In this regard, a higher water height has been shown to result in greater buoyancy and a decreased level of energy expenditure compared with walking on land at the same speed (Alkurdi et al., 2010; Gleim & Nicholas, 1989). In the current project, water height was set at 10 cm below the xiphoid process based on data indicating that walking on an underwater treadmill at a water height 10 cm below the xiphoid process resulted in higher aerobic demand and heart rate values compared with walking at a water height at or 10 cm above the xiphoid process (Alkurdi et al., 2010).

In the present investigation, body fat levels also decreased by nearly 4% after UTT. This reduction in overall fat percentage is larger than that noted in previous studies in which body fat was decreased by 1.0% in adults with type 2 diabetes who completed a 12-week endurance walking program (Marcus et al., 2008) or 22 weeks of combined aerobic and resistance training (Sigal et al., 2007) and is greater than the 1.5% decrease in body fat reported in obese patients with type 2 diabetes who underwent an intense 12-week insulin therapy program (Shah et al., 2011). The improvement in body fat level seen following UTT was also larger than the average decrease of 1.3%BF in middle-aged obese men and women who

performed 12 weeks of walking on underwater- or land-based treadmills at similar levels of exercise volume and intensity (Greene et al., 2009). The change in body fat percentage observed in our study does not appear to be associated with the elevated body mass index (BMI) of our participants ($BMI = 32.3 \text{ kg/m}^2 \pm 6.0$), as other intervention-based projects of adults with type 2 diabetes with similar BMI values have produced smaller decreases in relative body fat (Dunstan et al., 2002; Jones et al., 2009; Sigal et al., 2007). As mentioned earlier, it seems reasonable to imply that the marked reduction in %BF following UTT may be linked to the higher caloric expenditure associated with upper- and lower-body limb movement in water compared with walking on land (Alkurdi et al., 2010).

Following UTT, waist circumference was decreased by 8 cm, a reduction which is greater than changes noted in other long-term, land-based exercise studies (1.5–3 cm) conducted on middle-aged and older adults incorporating land-based aerobic and resistance training (Alkurdi et al., 2010; Sigal et al., 2007). Findings from previous research suggest that reductions in subcutaneous and visceral fat produced by aquatic training may be partially responsible for the decrease in WC measured in the current project (Jones et al., 2009).

Cardiorespiratory Function

Low aerobic fitness has been associated with heightened metabolic risk and an increased likelihood of cardiovascular disease (Jurca et al., 2005). While a direct evaluation of aerobic fitness is typically preferred, assessment of indirect measures of aerobic function, such as RHR and estimated $VO_{2\max}$, eliminates the need to exercise to volitional exhaustion, while providing a reasonably accurate estimation of cardiovascular risk and aerobic function in sedentary and overweight middle-aged adults (Jones et al., 2009; Jurca et al., 2005).

The RHR of our participants was nearly 10% lower (8 bpm) following UTT. In contrast, a nonsignificant decrease in RHR of 1 bpm was recorded in both post-menopausal women with type 2 diabetes who engaged in circuit resistance training for 12 weeks and older adults with type 2 diabetes who completed a 16-week resistance exercise training program (Castaneda et al., 2002; Kang et al., 2009). The extensive amount of cardiovascular exercise performed by participants during UTT, coupled with their relatively sedentary lifestyle, may partially account for the observed decrease in RHR measured in the current study.

The post-UTT increase in estimated $VO_{2\max}$ (~8% or $2.2 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) is consistent with relative gains in aerobic fitness in middle-aged and older adults with type 2 diabetes after 4 weeks of supervised land-based resistance and aerobic exercise (6.3%; Hordern et al., 2008) and 6 months of combined aerobic and resistance training (7.5%; Tan et al., 2012). The degree of improvement in cardiorespiratory fitness noted in our study was also similar to the 8.6% increase in $VO_{2\max}$ following a 16-week circuit resistance training program which employed gradual increments in intensity and duration and met current exercise guidelines for adults with type 2 diabetes (Kang et al., 2009). The increase in aerobic fitness in the current study was also similar to the average gain of $3.6 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ seen in middle-aged obese adults who completed 3 months of underwater- or land-based treadmill walking (Greene et al., 2009). While the overall increase in estimated maximal aerobic power fell within the standard error of estimate range for predicting $VO_{2\max}$ using

a single-stage treadmill test (Ebbeling et al., 1991), all study participants exhibited an increase in predicted VO_2max , lending credence to the notion that the improvement in aerobic fitness could be reasonably attributed to UTT.

The systematic rise in overall training volume in the current study enabled our participants to increase locomotor energy demands and improve estimated maximal aerobic power without experiencing the levels of pain and discomfort which sometimes accompany land-based walking in older adults (Pöyhönen et al., 2002). From a practical standpoint, a training-induced increase in VO_2max would also translate into reduced cardiovascular and metabolic strain and a diminished level of fatigue during physical activities requiring extended periods of walking (Boulé, Haddad, Kenny, Wells, & Sigal, 2001).

Leg Strength

Previous work has shown that adults with type 2 diabetes exhibit impaired mobility and 30–50% lower maximal leg strength values compared with healthy persons of similar age (Boulé et al., 2001). Results from our investigation demonstrated that hamstring peak torque at slow (25%), moderate (19%), and fast (31%) velocities and quadriceps peak torque at slow (8%) and moderate (12%) velocities were greater after UTT. These findings align with recent data indicating higher leg muscle strength values in elderly patients with type 2 diabetes following an integrated aerobic and resistance training program (Tan et al., 2012) and middle-aged adults with type 2 diabetes who engaged in resistance training (Larose et al., 2010). Because lean body mass was not significantly increased in our participants following 8 weeks of UTT, the increase in peak muscle torque may have been due to reduced leg muscle coactivation, which would increase net force production by agonist muscles (Häkkinen et al., 1998), or greater motor unit recruitment (Häkkinen et al., 1998; Pöyhönen et al., 2002).

Conclusion

While this exploratory project featured an innovative exercise therapy for adults with type 2 diabetes, the absence of a matched control group hampered our ability to firmly establish the health and functional benefits of underwater treadmill training in our sample. Given the scarcity of published data regarding this unique water-based walking program, additional studies featuring appropriate control groups and larger sample sizes are needed to confirm the effectiveness of UTT in adults with type 2 diabetes and refine training protocols. The assessment of dietary intake would also be useful in interpreting changes in body composition following UTT. In addition, completion of an extended period of UTT might yield larger improvements in glycemic control, as the average lifespan of a red blood cell can be as long as 120 days (Shima et al., 2012).

In conclusion, results from our preliminary study have demonstrated significant improvements in glycemic control, body composition, cardiorespiratory function, and leg strength in middle-aged adults with type 2 diabetes following 8 weeks of UTT. Given the commercial availability of portable underwater treadmills which are simple to use and similar in cost to quality land-based treadmills, our initial findings provide support for implementing UTT as a means of enhancing glyce-

mic control and health-related fitness in adults with type 2 diabetes and easing the transition to land-based walking programs in this population.

Acknowledgments

Parts of this study were presented in abstract form at the 2012 American Diabetes Association 72nd Scientific Sessions Conference, Philadelphia, Pennsylvania, June 8–12, 2012. The authors would like to thank all of the participants for their dedication and effort throughout the duration of the study.

References

- Alkurdi, W., Paul, R.D., Sadowski, K., & Dolny, G.D. (2010). The effect of water depth on energy expenditure and perception of effort in female subjects while walking. *International Journal of Aquatic Research and Education*, 4, 49–60.
- Allison, M.A., Manson, J.E., Aragaki, A., Eaton, C.B., Hsai, J., Phillips, L., . . . Trevisan, M. (2011). Resting heart rate and coronary artery calcium in postmenopausal women. *Journal of Women's Health*, 20(5), 661–669. [PubMed doi:10.1089/jwh.2010.2475](#)
- American College of Sports Medicine. (2014). *ACSM's guidelines for exercise testing and prescription* (9th ed.). Baltimore, MD: Lippincott, Williams, & Wilkins.
- American Association of Diabetes Educators. (2012). Diabetes and physical activity. *The Diabetes Educator*, 38(1), 129–132. [PubMed doi:10.1177/0145721711426094](#)
- Bennett, C.M., Guo, M., & Dharmage, S. (2007). HbA1c as a screening tool for detection of type 2 diabetes: A systematic review. *Diabetic Medicine*, 24(4), 333–343. [PubMed doi:10.1111/j.1464-5491.2007.02106.x](#)
- Blain, H., Vuillemin, A., Teissier, A., Hanesse, B., Guillemin, F., & Jeandel, C. (2001). Influence of muscle strength and body weight and composition on regional bone mineral density in healthy women aged 60 years and over. *Gerontology*, 47(4), 207–212. [PubMed doi:10.1159/000052800](#)
- Bocalini, D.S., Serra, A.J., Murad, N., & Levy, R.F. (2008). Water-versus land-based exercise effects on physical fitness in older women. *Geriatrics & Gerontology International*, 8(4), 265–271. [PubMed doi:10.1111/j.1447-0594.2008.00485.x](#)
- Boulé, N.G., Haddad, E., Kenny, G.P., Wells, G.A., & Sigal, R.J. (2001). Effects of exercise on glycemic control and body mass in type 2 diabetes mellitus: A meta-analysis of controlled clinical trials. *Journal of the American Medical Association*, 286(10), 1218–1227. [PubMed doi:10.1001/jama.286.10.1218](#)
- Carter, J.B., & Blaber, A.P. (2003). Effect of endurance exercise on autonomic control of heart rate. *Sports Medicine (Auckland, N.Z.)*, 33(1), 33–46. [PubMed doi:10.2165/00007256-200333010-00003](#)
- Castaneda, C., Layne, J.E., Munoz-Orians, L., Gordon, P.L., Walsmith, J., Foldvari, M., . . . Nelson, M.E. (2002). A randomized controlled trial of resistance exercise training to improve glycemic control in older adults with type 2 diabetes. *Diabetes Care*, 25(12), 2335–2341. [PubMed doi:10.2337/diacare.25.12.2335](#)
- Christ-Roberts, C.Y., Pratipawatr, T., Pratipawatr, W., Berria, R., Belfort, R., & Mandarino, L.J. (2003). Increased insulin receptor signaling and glycogen synthase activity contribute to the synergistic effect of exercise on insulin action. *Journal of Applied Physiology*, 95(6), 2519–2529. [PubMed](#)
- Dunstan, D.W., Daly, R.M., Owen, N., Jolley, D., De Courten, M., Shaw, J., & Zimmet, P. (2002). High-intensity resistance training improves glycemic control in older patients with type 2 diabetes. *Diabetes Care*, 25(10), 1729–1736. [PubMed doi:10.2337/diacare.25.10.1729](#)

- Ebbeling, C.B., Ward, A., Puleo, E.M., Widrick, J., & Rippe, J.M. (1991). Development of a single-stage submaximal treadmill walking test. *Medicine and Science in Sports and Exercise*, 23(8), 966–973. [PubMed doi:10.1249/00005768-199108000-00014](#)
- Eriksson, J., Taimela, S., Eriksson, K., Parviainen, S., Peltonen, J., & Kujala, U. (1997). Resistance training in the treatment of non-insulin-dependent diabetes mellitus. *International Journal of Sports Medicine*, 18, 242–246. [PubMed doi:10.1055/s-2007-972627](#)
- Gebel, E. (2013). Meet your A1c. *Diabetes Forecast*, 2, 1–3.
- Giaquinto, S., Ciotola, E., & Margutti, F. (2007). Gait in the water: A comparison between young and elderly subjects. *Disability and Rehabilitation*, 29(9), 727–730. [PubMed doi:10.1080/09638280600926314](#)
- Gleim, G.W., & Nicholas, J.A. (1989). Metabolic costs and heart rate responses to treadmill walking in water at different depths and temperatures. *American Journal of Sports Medicine*, 17(2), 248–252. [PubMed doi:10.1177/036354658901700216](#)
- Greene, N.P., Lambert, B.S., Greene, E.S., Carbuhn, A.F., Green, J.S., & Crouse, S.F. (2009). Comparative efficacy of water and land treadmill training for overweight or obese adults. *Medicine and Science in Sports and Exercise*, 41(9), 1808–1815. [PubMed doi:10.1249/MSS.0b013e3181a237ff](#)
- Häkkinen, K., Kallinen, M., Izquierdo, M., Jokelainen, K., Lassila, H., Malkia, E., . . . Alen, M. (1998). Changes in agonist-antagonist EMG, muscle CSA, and force during strength training in middle-aged and older people. *Journal of Applied Physiology*, 84(4), 1341–1349. [PubMed](#)
- Hordern, M.D., Cooney, L.M., Beller, E.M., Prins, J.B., Marwick, T.H., & Coombes, J.S. (2008). Determinants of changes in blood glucose response to short-term exercise training in patients with Type 2 diabetes. *Clinical Science*, 115(9), 273–281. [PubMed doi:10.1042/CS20070422](#)
- Jones, L.M., Meredith-Jones, K., & Legge, M. (2009). The effect of water-based exercise on glucose and insulin response in overweight women: A pilot study. *Journal of Women's Health*, 18(10), 1653–1659. [PubMed doi:10.1089/jwh.2008.1147](#)
- Jurca, R., Jackson, A.S., LaMonte, M.J., Morrow, J.R., Jr., Blair, S.N., Wareham, N.J., . . . Laukkanen, R. (2005). Assessing cardiorespiratory fitness without performing exercise testing. *American Journal of Preventive Medicine*, 29(3), 185–193. [PubMed doi:10.1016/j.amepre.2005.06.004](#)
- Kang, S., Woo, J.H., Shin, K.O., Kim, D., Lee, H.J., Kim, Y.J., & Yeo, N.H. (2009). Circuit resistance exercise improves glycemic control and adipokines in females with type 2 diabetes mellitus. *Journal of Sports Science and Medicine*, 8(4), 682–688. [PubMed](#)
- Kharroubi, A.T., Darwish, H.M., Al-Halaweh, A.I., & Khammash, U.M. (2014). Evaluation of glycated hemoglobin (HbA1c) for diagnosing type 2 diabetes and prediabetes among Palestinian Arab population. *PLoS ONE*, 9(2), e88123. [PubMed doi:10.1371/journal.pone.0088123](#)
- Lanshammar, K., & Ribom, E.L. (2011). Differences in muscle strength in dominant and non-dominant leg in females aged 20-39 years—a population-based study. *Physical Therapy in Sport*, 12(2), 76–79. [PubMed doi:10.1016/j.ptsp.2010.10.004](#)
- Larose, J., Sigal, R.J., Boulé, N.G., Wells, G.A., Prud'homme, D., Fortier, M.S., . . . Kenny, G.P. (2010). Effect of exercise training on physical fitness in type II diabetes mellitus. *Medicine and Science in Sports and Exercise*, 42(8), 1439–1447. [PubMed doi:10.1249/MSS.0b013e3181d322dd](#)
- Lind, E., & Ekkekakis, P. (2005). What intensity of physical activity do formerly sedentary middle-aged women select? Evidence of a coherent pattern from physiological, perceptual, and affective markers. *Preventive Medicine*, 40(4), 407–419. [PubMed doi:10.1016/j.ypmed.2004.07.006](#)
- Marcus, R.L., Smith, S., Morrell, G., Addison, O., Dibble, L.E., Wahoff-Stice, D., & Lastayo, P.C. (2008). Comparison of combined aerobic and high-force eccentric resistance exercise with aerobic exercise only for people with type 2 diabetes mellitus. *Physical Therapy*, 88(11), 1345–1354. [PubMed doi:10.2522/ptj.20080124](#)

- Menshikova, E.V., Ritov, V.B., Fairfull, L., Ferrell, R.E., Kelley, D.E., & Goodpaster, B.H. (2006). Effects of exercise on mitochondrial content and function in aging human skeletal muscle. *Journal of Gerontology*, 61(6), 534–540. [PubMed](#)
- Pöyhönen, T., Sipilä, S., Keskinen, K.L., Hautala, A., Savolainen, J., & Mälkiä, E. (2002). Effects of aquatic resistance training on neuromuscular performance in healthy women. *Medicine and Science in Sports and Exercise*, 34, 2103–2109. [PubMed doi:10.1249/01.MSS.0000039291.46836.86](#)
- Praet, S.F., & van Loon, L.J. (2007). Optimizing the therapeutic benefits of exercise in type 2 diabetes. *Journal of Applied Physiology*, 103(4), 1113–1120. [PubMed doi:10.1152/japplphysiol.00566.2007](#)
- Sayer, A.A., Dennison, E.M., Syddall, H.E., Gilbody, H.J., Phillips, D.I., & Cooper, C. (2005). Type 2 diabetes, muscle strength, and impaired physical function: The tip of the iceberg? *Diabetes Care*, 28(10), 2541–2542. [PubMed doi:10.2337/diacare.28.10.2541](#)
- Shah, P.K., Mudaliar, S., Chang, A.R., Aroda, V., Andre, M., Burke, P., & Henry, R.R. (2011). Effects of intensive insulin therapy alone and in combination with pioglitazone on body weight, composition, distribution and liver fat content in patients with type 2 diabetes. *Diabetes, Obesity & Metabolism*, 13(6), 505–510. [PubMed doi:10.1111/j.1463-1326.2011.01370.x](#)
- Shima, K., Chujo, K., Yamada, M., Komatsu, M., Noma, Y., & Mizuguchi, T. (2012). Lower value of glycated haemoglobin relative to glycaemic control in diabetic patients with end-stage renal disease not on haemodialysis. *Annals of Clinical Biochemistry*, 49, 68–74. [PubMed doi:10.1258/acb.2011.011161](#)
- Sigal, R.J., Kenny, G.P., Boulé, N.G., Wells, G.A., Prud'homme, D., Fortier, M., . . . Jaffey, J. (2007). Effects of aerobic training, resistance training, or both on glycemic control in type 2 diabetes: A randomized trial. *Annals of Internal Medicine*, 147(6), 357–369. [PubMed doi:10.7326/0003-4819-147-6-200709180-00005](#)
- Snowling, N.J., & Hopkins, W.G. (2006). Effects of different modes of exercise training on glucose control and risk factors for complications in type 2 diabetic patients. *Diabetes Care*, 29(11), 2518–2527. [PubMed doi:10.2337/dc06-1317](#)
- Stevens, S., & Morgan, D.W. (2010). Underwater treadmill training in adults with incomplete spinal cord injuries. *Journal of Rehabilitation Research and Development*, 47(7), vii–x. [PubMed doi:10.1682/JRRD.2010.04.0068](#)
- Tan, S., Li, W., & Wang, J. (2012). Effects of six months of combined aerobic and resistance training for elderly patients with a long history of type 2 diabetes. *Journal of Sports Science and Medicine*, 11(3), 495–501. [PubMed](#)
- Umpierre, D., Ribeiro, P.B., Kramer, C.K., Leitao, C.B., Zucatti, A.N., Azevedo, M.J., . . . Schaan, B.D. (2011). Physical activity advice only or structure exercise training and association with HBA1C levels in type 2 diabetes. *Journal of the American Medical Association*, 305(17), 1790–1799. [PubMed doi:10.1001/jama.2011.576](#)
- Zakas, A. (2006). Bilateral isokinetic peak torque of quadriceps and hamstring muscles in professional soccer players with dominance on one or both two sides. *Journal of Sports Medicine and Physical Fitness*, 46(1), 28–35. [PubMed](#)

STATEMENTS

ILS Declaration and Position Statement

Please visit <http://journals.HumanKinetics.com/IJARE> to view two important declarations and position statements that come from the International Life Saving Federation (ILS) courtesy of Justin Scarr. The first is the final conference declaration on a commitment to reduce and eliminate drowning that was produced by delegates to the World Conference on Drowning Prevention (WCDP) in 2011.

The second document is the ILS Position Statement on Development Aid Effectiveness, which addresses issues important to many nongovernmental organizations (NGOs) relative to how aid to low- and middle-income countries can be most effectively disseminated.