Comparative Efficacy of Water and Land Treadmill Training for Overweight or Obese Adults

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ABSTRACT

GREENE, N. P., B. S. LAMBERT, E. S. GREENE, A. F. CARBUHN, J. S. GREEN, and S. F. CROUSE. Comparative Efficacy of Water and Land Treadmill Training for Overweight or Obese Adults. *Med. Sci. Sports Exerc.*, Vol. 41, No. 9, pp. 1808–1815, 2009. **Purpose**: No known previous research has been published to explore the efficacy of underwater treadmill (UTM) exercise training for the obese. Thus, the purpose of this study was to compare changes in physical fitness, body weight, and body composition in physically inactive, overweight, and obese adults after 12 wks of land treadmill (LTM) or UTM training. **Methods**: Fifty-seven physically inactive, overweight, and obese men (n = 25) and women (n = 32) participated in this investigation. The mean ± SEM age, weight, body mass index (BMI), and $\dot{V}O_{2max}$ upon entry were 44 ± 2 yr, 90.5 ± 2.4 kg, 30.5 ± 0.7 kg·m^{-2}, and 27.1 ± 0.7 mL O_2·kg^{-1}·min^{-1}, respectively. Subjects were randomly assigned to exercise three times per week for 12 wk on either LTM (n = 29) or UTM (n = 28) matched for intensity and volume. Session volume was progressively increased from 250 to 500 kcal per session by week 6 and remained at 500 kcal through week 12. Before and after training, $\dot{V}O_{2max}$ was assessed by the Bruce treadmill protocol with open-circuit calorimetry, and body composition was assessed by dual-energy ray absorptiometry. Data were analyzed by a 2 (training) × 2 (exercise mode) × 2 (gender) ANOVA repeated across training (α = 0.05). **Results**: Training responses were not different between genders. After either UTM or LTM training, $\dot{V}O_{2max}$ was significantly increased (+3.6 ± 0.4 mL O_2·kg^{-1}·min^{-1}), whereas body weight (−1.2 ± 0.3 kg), BMI (−0.56 ± 0.11 kg·m^{-2}), body fat percentage (−1.3% ± 1.3%), and fat mass (−1.1 ± 0.3 kg) were significantly reduced (pooled means for UTM and LTM). Regional leg lean body mass (LBM) was significantly increased with both CTM and UTM (0.4 ± 0.3 and 0.8 ± 0.2 kg, respectively). An increase in total LBM approached significance with UTM training only (+0.6 ± 0.3 kg, P = 0.0599). **Conclusions**: UTM and LTM training are equally capable of improving aerobic fitness and body composition in physically inactive overweight individuals, but UTM training may induce increases in LBM. **Key Words:** BODY COMPOSITION, $\dot{V}O_{2max}$, AEROBIC EXERCISE, AQUATIC EXERCISE, WEIGHT LOSS

Data from the 2007 Behavioral Risk Factor Surveillance System demonstrate that more than 60% of the US population is currently overweight or obese (2). Obesity and sedentary lifestyle are well-known correlates of premature mortality, chronic disease morbidity, and impaired capability to perform activities of daily living (23,24). In recognition of these heath risks, the American College of Sports Medicine (ACSM) lists obesity and physical inactivity among the major risk factors for coronary heart disease and recommends exercise training to reduce risk (20,25). In particular, aerobic exercise training is known to counteract obesity by promoting reductions in body weight, body fat, and waist girth while raising maximal aerobic capacity ($\dot{V}O_{2max}$), reducing HR and reducing blood pressure at rest and during submaximal exercise (12,21). These changes occur independent of dietary intervention while providing the added benefit of preserving lean mass (4,16).

Despite the proven health benefits of aerobic exercise training, traditional modes, such as land walking and running, are often associated with an increased risk of musculoskeletal injury due to accumulated stress on the lower extremities (7,22,32), particularly in the obese. Furthermore, pain and injury from exercise are often cited as reasons for discontinuing exercise training (5). To counter the joint injuries and orthopedic problems that often limit exercise in the obese (35), the ACSM (1) recommends non–weight-bearing exercise for physical training in this population. In this regard, aquatic aerobic exercise reduces the stress on the lower extremities and spine (15) and has been recommended for individuals who are overweight and who have orthopedic diseases, such as osteoarthritis (32). To date, however, few well-controlled studies have been published

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to quantify the effectiveness of aerobic water-based exercise training. Those that exist show that persons performing deep-water running, water walking, and aquatic dance training generally demonstrate similar improvements in aerobic capacity (e.g., $\uparrow\dot{V}O_{2max}$) as those performing traditional land-based aerobic exercise training (13,28,30).

Recently, a variable-speed underwater treadmill (UTM) system with adjustable water depth and frontal resistance provided by pump-driven directional water jets has been used as a novel mode of aquatic exercise. This system theoretically provides a more favorable mode of exercise for the overweight and obese, in that walking or jogging intensity (velocity and resistance) can be controlled, whereas the buoyancy of water reduces the impact force of ambulation. Up to now, the UTM has been used most frequently as a treatment modality in sports injury or orthopedic rehabilitation settings and has only recently been used with obese individuals (26). Without more definitive studies, practitioners cannot be certain that UTM exercise training will yield benefits matching those realized by participating in more traditional forms of exercise.

We and others have shown that submaximal and maximal UTM and land treadmill (LTM) exercise produce similar acute physiological responses (18,19,29). Thus, to extend our previous findings, we hypothesized that UTM and LTM training adaptations, including changes in body weight, would likewise be similar as long as training volume and intensity were matched. Therefore, our purpose in this study was to compare LTM and UTM training by overweight and obese men and women with respect to changes in body composition, body weight loss, and cardiovascular fitness. We designed the exercise training regimen to be consistent with that recommended by the ACSM (1) for general cardiovascular fitness.

METHODS

Subjects. Physically inactive, overweight, and obese men and women were recruited from the Texas A&M University and the College Station, Texas, communities to participate in the study. Potential volunteers were recruited through informational flyers, through e-mail announcements, and by word of mouth. Volunteers were screened to ensure that they had not participated in regular aerobic activity for the previous 3 months (physically inactive) and were classified as overweight or obese by either body mass index (BMI) or percent body fat as measured by dual-energy ray absorptiometry (DEXA; Lunar Prodigy; GE Healthcare, Madison, WI). Subjects were stratified according to the ACSM standards for risk of cardiovascular disease, and those for whom it was required underwent a physical examination by a cardiologist before participation in the experiment (1). Fifty-seven of the original 78 volunteers completed all required aspects of the study, including attendance at ≥85% of all exercise training sessions, and their data were included in the data analysis. Data from the remaining 21 subjects originally recruited were excluded for the following reasons: subject was positive in the cardiac stress test on the entry physical, failure to complete the required 85% minimal attendance to training sessions, and dropout due to injury or time constraints. In addition, data from one subject in the UTM training group were not included in the analysis of body weight and composition measures because they did not comply with the nutritional instructions for the study. Preliminary physiological characteristics of the 57 subjects who completed the study are presented in Table 1. The mean ± SEM age, weight, BMI, percent body fat, and relative $\dot{V}O_{2max}$ of subjects upon entry were 44 ± 2 yr, 90.5 ± 2.4 kg, 30.5 ± 0.7 $kg{\cdot}m^{-2}$, 39.5% ± 1.2%, and 27.5 ± 0.7 mL $O_2{\cdot}kg^{-1}{\cdot}min^{-1}$, respectively. Of the 57 subjects completing the study, 51 had a BMI that classified them as overweight (>25 $kg{\cdot}m^{-2}$), 28 of which were classified as obese (>30 $kg{\cdot}m^{-2}$). Forty-seven of the 57 subjects upon entry had a body composition ≥30% fat as measured by DEXA.

General study protocol. All methods and procedures were approved by the institutional review board for human subjects in research of the Texas A&M University. On the first visit to the laboratory, subjects were informed of the study procedures and read and signed an institutionally approved informed consent. At this time, instructions were provided for completing physical activity and diet records (methods to follow). Physiological and demographic assessments were completed on the second visit to the laboratory (methods to follow). Within 2 wks of testing, subjects were matched for age, gender, and BMI and then randomly assigned to 12 wks of either LTM or UTM training. All physiological and demographic testing procedures were repeated within 4 d after the final exercise training session.

Diet and activity logs. Subjects were instructed to maintain their accustomed dietary and physical activity habits throughout the course of the study. No attempt was made to modify diet or activity outside of the exercise

TABLE 1. Demographic data of subjects upon entry to the study.

	UTM			LTM		
	Men	Women	Total	Men	Women	Total
Number	13	15	28	12	17	29
Age (yr)	42 ± 4 (24–56)	47 ± 3 (34–66)	45 ± 2 (24–66)	42 ± 3 (28–59)	44 ± 3 (21–63)	43 ± 2 (21–63)
Weight (kg)	98.4 ± 5.0 (79.8–129.8)	85.7 ± 4.5 (70.5–125.5)	90.3 ± 3.4 (70.5–129.8)	100.0 ± 3.0 (83.4–118.6)	82.2 ± 4.6 (50.5–114.5)	89.6 ± 3.4 (50.5–118.6)
BMI ($kg{\cdot}m^{-2}$)	30.3 ± 1.1 (26.3–39.1)	30.4 ± 1.6 (22.3–43.3)	30.4 ± 0.9 (22.2–41.5)	31.2 ± 0.9 (28.3–38.5)	30.3 ± 1.7 (18.5–42.6)	30.7 ± 1.0 (18.5–42.6)
Body composition (% fat)	33.8 ± 1.8 (23.7–43.5)	44.7 ± 1.4 (35.2–53.5)	39.7 ± 1.6 (23.7–53.5)	34.4 ± 1.6 (29.1–47.4)	43.1 ± 2.5 (23.9–53.3)	39.4 ± 1.8 (23.9–53.3)

Values are presented as means ± SEM (range).

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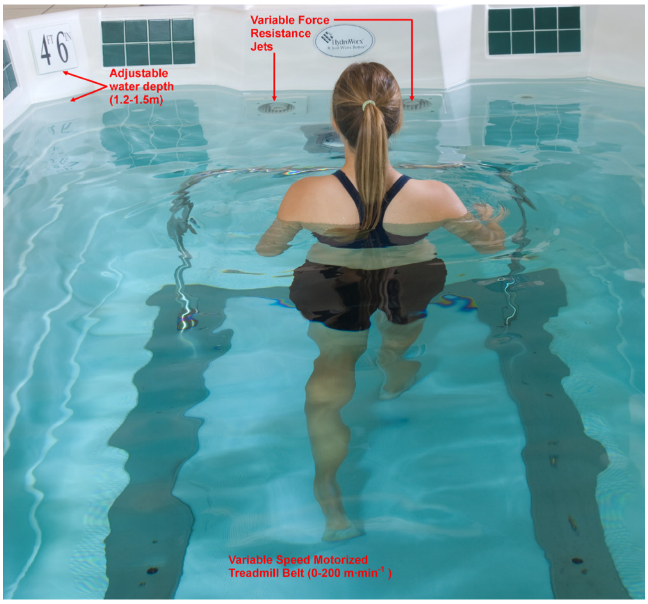

FIGURE 1—UTM. HydroWorx 1000™ series treadmill as used in the current study with markers denoting motorized belt and frontal resistance jets. The variable speed motorized treadmill from 0 to 200 m·min^{-1} (0–7.5 mph) allows for precise control of running velocity; in addition, variable-force resistance jets are configured to push against the subject, providing resistance to forward ambulation.

training protocol. To verify compliance with these instructions, dietary and activity habits were assessed on two occasions coinciding with the beginning and end of exercise training. Subjects were instructed to complete dietary and physical activity records on days that would best represent their normal daily habits. On both occasions, dietary logs were recorded for three consecutive days, including one weekend day. The 3-d dietary records were analyzed for total caloric intake and for carbohydrate, fat, and protein composition using commercially available computer software (Food Processor® 8.4; ESHA Research, Salem, OR). The physical activity records used were an adaptation of a previously described protocol for physical activity recall (6). Activity records were recorded for seven consecutive days and were analyzed for total energy expenditure.

Physiological assessments. Body composition, including regional and whole-body percent fat and lean body mass, was assessed using DEXA. Waist girths and waist-to-hip ratios were measured as indices of regional adiposity. An incremental maximal graded exercise test (GXT) was conducted on a motor-driven treadmill according to the Bruce protocol (10). Oxygen consumption during exercise was assessed using an automated metabolic gas analysis system (CPX/D Exercise Stress Testing System, Medical Graphics, Minneapolis, MN; or Oxycon Pro, Erich JAEGER, Hoechberg, Germany) calibrated with gasses of known concentration before and after each exercise test. In addition, airflow pneumotachs were also calibrated at these times according to the manufacturer's specifications. Each subject was tested using the same metabolic equipment at pretraining and posttraining assessment periods. $\dot{V}O_{2max}$ was taken as the highest 15-s average oxygen uptake achieved during the exercise test. HR and rhythm were monitored continuously from a 12-lead electrocardiogram. RPE using a Borg 15-point scale ranging from 6 to 20 (8) and manual blood pressures were obtained during the last 30 s of each treadmill stage and at maximal exercise. At least two of the following criteria were required for the maximal exercise test to be considered valid: 1) achievement of maximum HR within 10 bpm of the age-predicted maximum; 2) RPE $\geq$18; 3) respiratory exchange ratio >1.1 at maximal exertion; or 4) O_2 uptake plateau despite further increases in workload. The same skilled laboratory personnel consistently performed all physiological measurements.

Exercise training. Subjects exercised three times per week during the 12-wk period. The UTM (HydroWorx 1000™ series; HydroWorx International, Inc., Middletown, PA) used for this study was equipped with a variable-speed motor-driven treadmill and pump-driven water jets providing frontal resistance (Fig. 1). The UTM water depth was standardized to the level of each subject's fourth intercostal space, and the jets were directed at the umbilicus. LTM exercise training was conducted on a standard motor-driven treadmill.

The exercise prescription and the training progression for this study are shown in Table 2. The three training sessions per week were performed by all subjects at an equivalent caloric expenditure, and exercise intensity was determined from the maximal GXT. Briefly, HR and RPE obtained during each stage of the GXT were regressed on $\dot{V}O_2$ for each subject. Each subject's regression was subsequently used to calculate his or her training HR and RPE, corresponding to the desired training intensity (%$\dot{V}O_{2max}$). Treadmill velocity and grade (or jet resistance for UTM) were adjusted as necessary during the training session to attain the HR and the RPE that matched the prescribed intensity. Individual energy costs (kcal·min^{-1}) of exercise at the various exercise intensities were estimated as the product of $\dot{V}O_2$ (L O_2·min^{-1}) and the respiratory exchange ratio energy–oxygen equivalent (kcal·L^{-1} O_2) measured during the GXT at each respective intensity of interest. Using this relationship, the exercise duration (min) required to expend the required kilocalorie of energy per exercise session was calculated for each subject. HR and RPE were recorded during each exercise session as a means of tracking intensity. As a further check on intensity and prescribed caloric

TABLE 2. Exercise training protocol.

Week	Frequency (sessions per week)	Intensity (%$\dot{V}O_{2max}$)	kcal per session
1	3	60	250
2	3	65	300
3	3	70	350
4	3	75	400
5	3	80	450
6	3	85	500
Repeat $\dot{V}O_{2max}$ testing and recalculate EX RX week 6			
7–12	3	85	500

EXRX signifies exercise prescription.

TABLE 3. Aerobic fitness and body composition changes after exercise training.

Variable	LTM		UTM		Significance
	Pretraining	Posttraining	Pretraining	Posttraining	
Diet and physical activity					
Caloric expenditure (kJ·d^{-1})	12,923.4 ± 486.6	12,885.9 ± 532.1	12,576.1 ± 501.9	12,751.3 ± 491.0	NS
Dietary intake (kJ·d^{-1})	11,173.4 ± 955.5	10,370.4 ± 1020.7	9930.3 ± 672.3	9605.4 ± 683.8	NS
Maximal aerobic capacity					
$\dot{V}O_{2max}$ (L·min^{-1})	2.4 ± 0.1	2.7 ± 0.1	2.5 ± 0.1	2.8 ± 0.1	<0.0001
$\dot{V}O_{2max}$ (mL O_2·kg^{-1}·min^{-1})	27.29 ± 1.19	31.24 ± 1.31	26.91 ± 1.22	30.17 ± 1.24	<0.0001
Body mass and girth measurements					
Body mass (kg)	89.6 ± 3.4	88.1 ± 3.2	90.3 ± 3.4	89.6 ± 3.3	<0.001
BMI (kg·m^{-2})	30.7 ± 1.0	30.1 ± 1.0	29.9 ± 0.9	29.4 ± 0.9	<0.0001
Waist (cm)	97.5 ± 3.3	93.7 ± 3.0	96.8 ± 2.3	93.2 ± 2.0	<0.0001
Hip (cm)	112.0 ± 2.0	109.7 ± 2.0	112.0 ± 2.0	110.2 ± 2.3	<0.001
Waist–hip ratio	0.87 ± 0.02	0.85 ± 0.02	0.86 ± 0.02	0.84 ± 0.01	<0.05
Total body composition					
Android (% fat)	43.8 ± 2.2	42.3 ± 2.1	45.7 ± 1.2	44.3 ± 1.4	<0.01
Gynoid (% fat)	43.9 ± 1.9	43.3 ± 2.0	43.8 ± 2.0	42.5 ± 2.1	<0.01
Android–gynoid ratio	1.03 ± 0.06	1.02 ± 0.06	1.09 ± 0.05	1.09 ± 0.05	NS
Lean body mass (kg)	51.2 ± 2.2	51.1 ± 2.1	51.9 ± 2.4	52.5 ± 2.4[a]	NS
Total fat mass (kg)	33.9 ± 2.3	32.8 ± 2.2	33.7 ± 2.0	32.8 ± 2.1	<0.01
Regional body composition					
Arm (% fat)	34.0 ± 2.0	33.4 ± 2.0	32.3 ± 2.0	31.4 ± 2.2	<0.01
Leg (% fat)	40.1 ± 2.3	39.4 ± 2.3	39.3 ± 2.2	38.5 ± 2.3	<0.01
Trunk (% fat)	41.1 ± 1.9	40.2 ± 2.0	42.3 ± 1.4	40.8 ± 1.6	<0.01
Regional lean mass					
Arm lean mass (kg)	5.6 ± 0.4	5.6 ± 0.4	5.9 ± 0.4	6.0 ± 0.4	NS
Trunk lean mass (kg)	24.9 ± 5.9	24.5 ± 5.1	25.2 ± 6.1	25.0 ± 5.9	NS
Regional fat mass					
Arm fat mass (kg)	2.8 ± 0.2	2.7 ± 0.2	2.7 ± 0.2	2.7 ± 0.2	NS
Leg fat mass (kg)	11.9 ± 0.9	11.7 ± 0.9	11.4 ± 0.8	11.5 ± 0.9	NS
Trunk fat mass (kg)	18.3 ± 1.4	17.5 ± 1.4	18.8 ± 1.3	17.8 ± 1.4	<0.001

Significance values reflect posttraining changes for both exercise training modes. Values are presented as means ± SEM.
[a] Total lean body mass approached significance with UTM training only (mode by training $P = 0.0599$).

expenditure, a metabolic cart was used to sample $\dot{V}O_2$ from each subject during a training session in weeks 1, 4, 7, and 10. Thus, duration and intensity were controlled so that all subjects expended an equivalent number of kilocalorie of energy per exercise session. To account for cardiovascular training, each subject repeated a maximal GXT after the sixth week of training, new HR–$\dot{V}O_2$ relationships were calculated, and exercise training HR was adjusted accordingly to match the prescribed intensity.

Statistical analyses. The independent factors in this study were training (before or after), mode of exercise (UTM or LTM), and gender. Dependent variables of interest included $\dot{V}O_{2max}$ as a measure of aerobic fitness and body composition variables to include whole-body and regional body fat and lean mass measures. A 2 (training) × 2 (exercise mode) × 2 (gender) ANOVA repeated across training was used as the global analysis for each dependent variable of interest. The comparison-wise error rate, α, was set at 0.05 for all statistical tests. All data were analyzed using the Statistical Analysis System (version 9.13; SAS, Cary, NC).

RESULTS

Pretraining physiological characteristics of subjects in each training mode by gender are presented in Table 1. No significant differences in any of these characteristics were found between UTM and LTM training groups at the beginning of exercise training. No significant differences were found in daily energy expenditure or in dietary intake after exercise training (Table 3). This confirms that the subjects in our study complied with our directive that they refrain from altering their habitual diet or physical activity habits outside the physical training we prescribed. Thus, all observed changes during the study were considered by us to result from the prescribed exercise training and not as a consequence of an unwanted change in their dietary or activity habits outside the scope of the study. In total, 90% of all prescribed exercise sessions were completed. Although some baseline differences were found between men

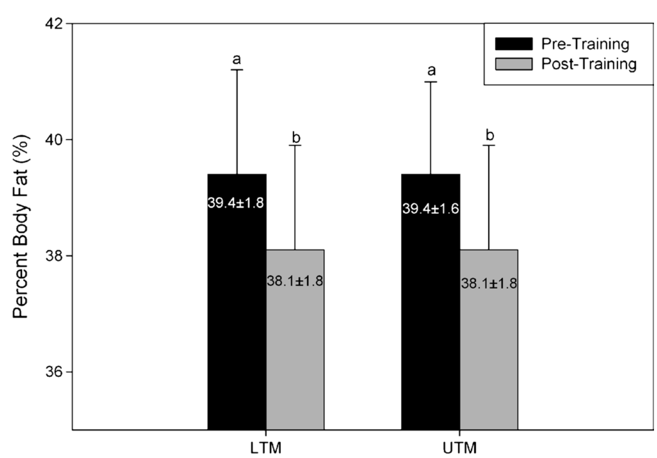

FIGURE 2—Percent body fat before and after 12 wk of exercise training for both exercise training modes. Data are presented as means ± SEM. Bars with differing letters are significantly different within training mode (P < 0.05).

and women (Table 1), our statistical analyses showed that there were no differential effects of gender on exercise training outcomes (i.e., no interaction due to gender); therefore, all exercise training data were collapsed across gender for subsequent analysis and for the presentation of results that follow.

Aerobic training effects for both training modes (UTM and LTM) are shown in Table 3. $\dot{V}O_{2max}$ was significantly increased after training regardless of training mode (+0.3 ± 0.03 L $O_2 \cdot min^{-1}$ or +3.6 ± 0.4 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$, $P <$ 0.0001), with no differential effects of training mode detected (no interaction due to exercise mode). Results of the GXT performed during week 6 of training revealed mean increases in $\dot{V}O_{2max}$ (+0.2 L $O_2 \cdot min^{-1}$ or +2.8 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$) from the pretraining values; these data were not end-point variables and thus were not included in statistical analyses.

Changes in total and regional body composition and total and regional fat and lean body mass are also given in Table 3. Body mass (−1.2 ± 0.3 kg, $P < 0.001$), BMI (−0.56 ± 0.11 $kg \cdot m^{-2}$, $P < 0.0001$), waist girth (−2.5 ± 0.5 cm, $P < 0.0001$), hip girth (−1.7 ± 0.4 cm, $P < 0.001$), and waist-to-hip ratio (−0.01 ± 0.005, $P < 0.05$) were all significantly lower after training regardless of mode. Moreover, percent body fat (−1.3% ± 1.8%, $P < 0.01$) was significantly reduced with both modes of training (Fig. 2). No differential effect of training mode was detected for any of the above measures. Interestingly, UTM training was accompanied by an average increase of 0.6 ± 0.3 kg (3.2%) in total lean body mass, a change from before training that approached significance ($P = 0.0599$). Comparatively, lean body mass was essentially unchanged (−0.1 ± 0.3 kg) after LTM training. Moreover, using DEXA to analyze body composition by body region showed that leg lean mass was significantly increased +0.4 ± 0.3 and +0.8 ± 0.2 kg after LTM and UTM training, respectively ($P < 0.01$; Fig. 3). In spite of the fact that the leg lean mass increase was twice as great after UTM training, the difference between modes was not statistically significant.

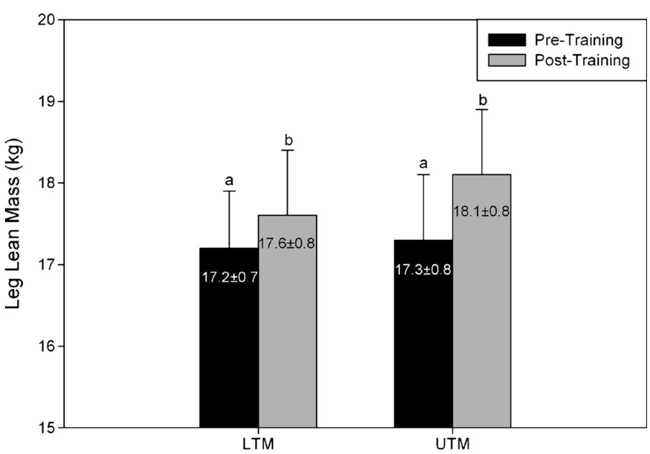

FIGURE 3—Leg lean mass (kg) before and after 12 wk of exercise training for both exercise training modes. Data are presented as means ± SEM. Bars with differing letters are significantly different within training mode (*P* < 0.05).

DISCUSSION

Our study is the first to show that novel UTM exercise training performed by overweight and obese men and women is an effective training modality, producing beneficial changes in body composition and improvements in physical fitness. Realized benefits of this mode of exercise, applied in a manner consistent with the recommendations of the ACSM (1) for improving health, were comparable to those which accompanied intensity and volume-matched LTM training in all dimensions measured. Of interest, lean body mass was maintained with both exercise modes despite reductions in total body weight. In fact, gains in total lean body mass were evident after UTM compared with LTM training (Table 3), a finding that approached statistical significance ($P = 0.0599$). The results of the current study validate the use of UTM as an effective exercise training tool in overweight and obese men and women. Furthermore, if it can be verified by future research in the obese, gains in lean mass produced by UTM training would prove to be an important comparative advantage of this mode of training over more traditional land-based treadmill exercise.

More specifically, we showed in the present study that BMI, percent body fat, and waist-to-hip ratio were all significantly reduced after 12 wks of either UTM or LTM exercise training (Table 3). BMI was reduced despite no loss in total lean body mass and a gain in leg lean mass in both training groups, highlighting that reductions in BMI were evidence of lost fat mass only. Such a reduction in BMI, although relatively small in just 12 wk of training, may be considered important because previously published data suggest that CHD mortality rate increases 30% with only a 5-$kg \cdot m^{-2}$ increment of BMI (23). Our finding that percent body fat was reduced by 1.3% after training agrees with the review by Wilmore (33), in which it was reported that a modest loss in percent body fat (−1.6%) can be expected with exercise training regimens ranging from 6 to 104 wk. Furthermore, in a meta-analysis, Ballor and Keesey (4) reported that modest reductions in body mass (−0.6 kg in women and −1.2 kg in men) and percent body fat (−1.7% in men and women) can be expected with both run/walk and cycling types of aerobic exercise training. These results are also consistent with those of Wing (34), who demonstrated an expected effect size of approximately 1 to 2 kg weight loss with exercise training alone. Our findings of an average weight loss of 1.2 kg corroborate these previous findings. In addition, our findings confirm our hypothesis that calorically matched UTM and LTM exercise training would produce comparable losses in body mass and body fat percentages. In contrast to our UTM findings, other aquatic studies in untrained subjects were generally negative for changes in body weight and composition (13,28,30). What is clear at present from our

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study is that both LTM and UTM training consistent with the recommendations of the ACSM (1) for health and fitness will similarly reduce body weight and body fat in physically inactive, overweight, and obese men and women.

By use of DEXA, we were also able to analyze whole-body and regional (trunk, leg, and arm) fat and lean mass. To the authors' knowledge, we are among the first to report such region-specific changes in body composition with any type of aerobic exercise training. Our DEXA analyses revealed an approximately 1-kg reduction in body total fat mass after either LTM or UTM training. Thus, our measured change in fat mass for 12 wks of training was similar to the 0.6- to 1.9-kg fat mass loss reported by Ballor and Keesey (4) after cycling or walk/run exercise training. The average reduction in fat mass (−1.0 kg) noted in our study was similar to the average reduction in total body weight (−1.2 kg) seen in the present study collapsed across both training groups. In addition, trunk regional fat mass was reduced by nearly 1.0 kg in our subjects regardless of training mode. This demonstrates that the predominant site of fat loss in our study was from the trunk region. These data corroborate our findings that waist girth was significantly reduced with training regardless of mode. Such findings add valuable support to the concept of CVD risk reduction by exercise training because a decrease in body fat in the abdominal region is associated with a greater reduction in CVD risk than decreases in fat stores from other body regions (14). Taken together, these data indicate a similar reduction in this important chronic disease risk marker by UTM and LTM exercise training, so long as frequency, intensity, and duration (i.e., caloric expenditure) of exercise are matched between training modes. That both modes were effective in improving body composition measures validates the efficacy of using UTM exercise for body weight and fat reduction in overweight and obese adults.

Our findings lend support to those of others who reported that lean body mass is maintained when exercise is included in a weight loss program. In contrast, lean body mass is lost with diet-only weight loss regimens (11,27). In this regard, it is interesting that our subjects who trained on the UTM demonstrated a +0.6 kg (+1.2%) average change in total lean body mass, which approached statistical significance (P = 0.0599). By comparison, no lean body mass change was found in LTM-trained subjects (−0.1 kg). Both UTM (+0.8 kg, 4.6%) and LTM (+0.4 kg, 2.3%) exercisers showed statistically significant gains in leg lean mass. To the authors' knowledge, we are the first to report such an increase in leg lean mass with aerobic exercise alone. However, longer-duration studies will be required to clarify and substantiate these findings.

It should be noted that we opted for a more conservative statistical treatment of the data in our study. Given the comparatively greater increase measured in total lean body mass and leg lean mass after UTM compared with LTM training, we opted to perform exploratory *post hoc* paired t-tests within each mode of training as well as two-sample t-tests on the posttraining data to compare means between the modes of exercise. The paired t-tests revealed no change in total lean mass with LTM training (P = 0.79), but the pretraining to posttraining change was significant for UTM training (P = 0.05). In addition, despite no differences between the UTM and the LTM groups in total body or leg lean mass before the training began (Table 3), both of these variables were significantly greater by t-test ($P < 0.001$) in the UTM exercisers compared with the LTM after training. We caution that based on our *post hoc* analyses, we cannot conclude that UTM was more effective than LTM in retaining or increasing lean body mass or leg lean mass in the face of weight loss. Future studies will be required to verify this to be the case. Related to these findings, it is of interest that Ballor and Keesey (4) in their meta-analysis concluded that an average increase of 0.8 kg of fat-free mass can be expected with cycle training, a comparable increase to that seen in our UTM subjects. At present, we can only speculate that any increase in lean body mass and leg lean mass with UTM training occurred as a response to a greater force requirement for ambulation through water, a denser medium than air. Any gains in leg lean mass suggest the potential for strength gains. Unfortunately, we did not measure leg strength in our study, but our previous work showing significant gains in leg strength after LTM training (17) argues in favor of improved strength in our subjects. More importantly, maintenance of lean body mass with both modes of exercise emphasizes the importance of exercise training to help limit the loss of lean tissue in any weight reduction program.

There is a broad agreement that $\dot{V}O_{2max}$ is an important indicator of aerobic fitness (31). In our present study of physically inactive men and women, $\dot{V}O_{2max}$ was significantly improved with both LTM (+3.95 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$) and UTM (+3.26 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$) training modes, with no significant difference between them. Our findings are similar to those of Reilly et al. (28), who found a mean increase of 4.5 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$ with both deep-water running and LTM training. Our data are also consistent with the findings of Avellini et al. (3), who showed that subjects training on a cycle ergometer at neck depth in water experienced similar improvements in $\dot{V}O_{2max}$ to those training on cycle ergometer on land. We speculate based on related research (23) that the improvement in $\dot{V}O_{2max}$ measured in our present study translates into a significant reduction in cardiovascular risk and all-cause mortality for our overweight and obese subjects. The ability of UTM and LTM to elicit similar improvements in $\dot{V}O_{2max}$ confirms the efficacy of UTM to not only improve body weight and composition but also improve aerobic fitness as well.

As previously stated, the repetitive forces associated with walking and jogging, both common forms of aerobic exercise, can result in pain and injury, especially in obese populations and in others suffering from orthopedic injury (7,22,32). Related to injury risk, Browning and Kram (9) reported greatly increased walking ground reaction forces and hip, knee, and ankle joint loads in the obese, which were a function of their body mass. In pilot work, we submerged a sample of our subjects to the level of the fourth intercostal space, the individualized water depth used in this study, and found that the average water-equivalent weight was approximately 25% of that on land. Taken with the results of Browning and Kram (9), it logically follows that ground reaction forces in our subjects exercising in the UTM would be substantially reduced. On this basis, we speculate that UTM exercise, in addition to its training benefits, may have the additional advantage of lowering overuse injury risk in the obese. Because pain and injury are often given as primary reasons for training dropout (5), reducing the incidence of injury would naturally improve training adherence in an obese population. Future research should address the issue of injury frequency with UTM training.

In conclusion, our results show that UTM training is a viable alternative to traditional LTM training for overweight and obese populations, producing modest reductions in body weight and improvements in body composition and aerobic capacity in 12 wk without dietary intervention. The UTM mode of exercise used in this study is also consistent with the ACSM's recommendation for non–weight-bearing exercise in the obese population (1). Thus, our findings provide practitioners with evidence that this novel form of exercise is effectual and can be confidently prescribed as a training modality in the treatment of adult obesity.

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