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The Effect of Water Depth on Energy Expenditure and Perception of Effort in Female Subjects While Walking

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The purpose of this study was to compare energy expenditure (EE), heart rate, and perceived effort during walking in water at several depths versus land in female participants. Eighteen females walked on three separate days on a land treadmill (Land) and in a water treadmill (ATM) at 30 °C at 6 speeds. Water depth was at the xiphoid (xip), 10 cm below (-10 cm), and 10 cm above xip (+10 cm). Heart rate (HR), oxygen consumption (VO_2), and carbon dioxide production (VCO_2) were recorded. RPE overall (RPE-O) and RPE legs (RPE-L) were solicited following each bout. Regardless of walking speed, EE and HR were influenced by water depth, with -10 cm significantly greater than xip, +10 cm and Land, and xip significantly greater than +10 cm and Land (all $p < .001$). Land EE and HR were similar to +10 cm. RPE-O was significantly higher for -10 cm vs. xip, +10 cm, and Land, while xip was greater than Land. RPE-L was greater for -10 cm vs. xip, +10 cm and Land, while xip was greater than +10 cm & Land. Our results concluded that small changes in water depth influences exercise EE, HR, and RPE. These differences are attributed to a changing relationship between drag resistances and buoyancy in water.

In recent years, the percentage of overweight and obese adults in the United States has continued to increase, with nearly one-third of adults classified as obese (Ogden, Carroll, Curtin et al., 2006). Obesity has been associated with increased risk of cardiovascular disease, diabetes, and other chronic conditions (National Taskforce on the Prevention and Treatment of Obesity, 2000). Obesity in middle-aged and older adults also increases the risk of physical disability (Daviglus, Liu, Yan et al., 2003).

The etiology of weight gain and obesity is complex, as many factors are involved in weight regulation. Physical inactivity has been demonstrated to be a clear contributor to obesity and is now considered a leading cause of death in the United States (Danaei et al., 2009). In addition, cardiorespiratory fitness levels are associated with lower incidences of preventable chronic diseases and mortality rates in both men and women (Blair & Morris, 2009).

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Walking is often recommended for overweight and obese individuals because of its practical nature (Brill, Perry, Parker, Robinson, & Burnett, 2002) and may be more convenient than other activities (Lafortuna, Agosti, Galli, Busti, Lazzer, & Sartorio, 2008). Unfortunately, walking on land places stress on the joints of the lower extremity and perhaps apply biomechanical loads that foster the development of orthopedic conditions such as osteoarthritis (Griffin & Guilak, 2005). Therefore, the recommendation of brisk walking to treat obesity (Pate, Pratt, & Blair, 1995) may inadvertently contribute to musculoskeletal disorders. In support of the use of a water environment, a recent study confirmed that walking in water provided a comparable improvement in aerobic capacity with a greater increase in leg lean body mass in previously inactive, overweight, and obese adults (Greene et al., 2009).

Furthermore, another factor that may influence an overweight or obese individual to continue a walking program is the relative effort required. When compared with normal weight individuals, the obese have to expend more energy while walking. For example, the net metabolic rate of walking in overweight/obese subjects is ~10% and may be as much as 45% greater than in normal weight individuals (Browning & Kram, 2005; Browning, Baker, Herron, & Kram, 2006; Foster et al., 1995). This added metabolic cost places them at a greater percentage of their maximum aerobic capacity (VO_{2peak}), making it more difficult to maintain recommended exercise durations.

In recent years, a new form of treadmill has become available for exercise training and rehabilitation—the aquatic treadmill (ATM). ATMs are designed to either have an individual walk on a treadmill submerged in a small pool in still water or incorporate a water flume where water flows by a subject at a rate comparable to the walking pace selected. In either condition, a major benefit of ATMs is the reduction in the vertical component of the ground reaction forces (GRF) subjects experience compared with land exercise (Nakazawa, Yano, & Miyashita, 1994). This reduction in vertical GRF is due to the buoyant effect of water and is a popular modality favored by physical therapists and patients because of the reduced loading, and hence pain, of the lower extremity (Hall, Skevington, Maddison, & Chapman, 1996). The magnitude of vertical GRF is related to water depth. Dependent upon water depth (i.e., umbilicus vs. 7th cervical vertebra), a subject may experience a reduction of ~57–85% in body weight, respectively (Harrison, Hillman, & Bulstrode, 1992). Therefore water depth can be adjusted to accommodate an overweight or obese individual's orthopedic condition.

Although numerous studies have evaluated the metabolic and cardiorespiratory responses during ATM walking in still water (Gleim & Nicholas, 1989; Hall, Macdonald, Maddison, & O'Hare, 1998; Pohl & McNaughton, 2003) or with a water flume (Hotta, Muraoka et al., 1993; Hotta, Ogaki, Kanaya, & Hagiwara, 1993; Hotta, Ogaki, Kanaya, Fujishima, & Hagiwara, 1994; Hotta, Ogaki, Kanaya & Fujishima 1995; Migita et al., 1994; Migita, Hotta, Ogaki, Kanaya, Fujishima, & Masuda 1996; Shimizu, Kosaka, & Fujishima, 1998; Shono et al., 2000; Shono, Fujishima, Hotta, Ogaki, & Masumoto, 2001; Shono, Fujishima, Hotta, Ogaki, & Ueda, 2001), only two have evaluated the effect of manipulating water depth (Gleim & Nicholas, 1989; Pohl & McNaughton, 2003). Gleim and Nicholas

(1989) contrasted walking rapidly at 6.44 kph in water depths of ankle, patella, midthigh, and umbilicus. Pohl and McNaughton (2003) compared walking 4.02 kph in waist and thigh deep water. Each study reported significantly higher VO_2 and HR as water depth decreased. We were interested in determining if more subtle changes in water depth (±10 cm) influenced cardiorespiratory responses and perceptions of effort.

The purpose of this study was to evaluate the effect of varying water depth on the cardiorespiratory responses and perceived effort of walking on a water treadmill (ATM) compared with walking on a land treadmill (Land). We were interested in determining if small changes in water depth could be an effective tool in adjusting exercise intensity and influence an individual's perception of exercise effort in female subjects.

Method

Participants

Eighteen female participants completed informed consent waivers consistent with the policy statement regarding the use of human participants and written informed consent as reviewed and approved by the University Human Assurance Committee. Participants (Table 1) ranged in age from 21 to 60 yrs and body mass index (BMI) of 21.5–44.9 (kg/m^2). All participants reported they were free of any acute or chronic orthopedic conditions of the lower extremity and did not have previous lower extremity surgery. All participants reported to have performed some type of aerobic exercise in the past six months, ranging from ≤ 6 sessions in 6 months to 5 sessions per week.

Table 1 Participants' Descriptive Statistics

Age (yr)	Height (cm)	Weight (kg)	BMI (kg/m_2)
45.1 ± 13	166.4 ± 4.9	80.1 ± 18	29.0 ± 6.2

Equipment

ATM protocols were performed in a HydroWorx 2000 (HydroWorx, Middletown, PA) that consisted of 2.6 × 3.9-m pool kept at 30°C with a treadmill built into an adjustable-height floor. The Land protocol was performed on a standard adjustable-incline treadmill (Woodway Demo S, Woodway Inc., Waukesha WI). Expired air was analyzed using an automated metabolic system (True One 2400, Parvo Medics, Sandy UT). Water-resistant chest-strap transmitters (Polar T31, Polar, Lake Success NY) were worn by participants to monitor heart rate (HR). Ratings of perceived exertion (RPE) for both overall (RPE-O) and legs (RPE-L) were assessed immediately after each exercise trial using Borg's 15-point RPE scale (Borg, 1982).

Protocol

Each participant walked on three separate days in one week on a land treadmill (TM) in 24°C air and on a separate week in a water treadmill (ATM) at 30°C. Each land session consisted of six 5-min walking bouts of 2.41, 3.22, 4.02, 4.83, 5.63, and 6.44 kph with three minutes of rest between each bout. Each water session was conducted at the same walking speeds as land but water depth was altered each session: at the xiphoid level (xip), 10 cm below xiphoid (-10 cm) and 10 cm above xiphoid (+10 cm), with each walking speed randomized. During each walking bout HR, oxygen consumption (VO_2) and carbon dioxide production (VCO_2) were recorded continuously (Table 2).

Table 2 Experimental Conditions

Condition	Walking Speed (kph)	Water Depth	Temperature
ATM	2.41, 3.22, 4.02, 4.83, 5.63, 6.44	10 cm above xyphoid (+10 cm); xyphoid, or: 10 cm below the xyphoid (-10 cm)	30°C
Land	2.41, 3.22, 4.02, 4.83, 5.63, 6.44	NA	24°C

All data were averaged over the last three minutes of each bout to represent the physiological response to that exercise condition. Energy expenditure (EE) in kilojoules per minute (kJ/min) was estimated by multiplying VO_2 by the caloric equivalent of oxygen (Lusk, 1928) multiplied by 4.184.

Statistics

EE and HR were modeled within a mixed linear framework using the Proc Mixed procedure in SAS (version 9.2), with water depth and the interactions between water depth and treadmill speed used as independent variables. EE for each water depth was modeled using BMI as an independent variable. Post exercise RPE-O and RPE-L were modeled using water depth and the interactions between water depth and treadmill speed used as independent variables. Subject-to-subject variation was modeled as a random effect and captured the repeated measures within-subject correlation using an AR(1) parameter. Post hoc differences were analyzed by observing the Tukey-Kramer adjusted P-values. P-values < 0.05 were considered statistically significant.

Results

Energy Expenditure

Regardless of walking speed, EE was influenced by water depth, with -10 cm (25.5 ± 10.1 kJ/min) significantly greater than xip (22.2 ± 8.34 kJ/min), +10 cm (18.6 ± 6.15 kJ/min), and Land (19.5 ± 7.56 kJ/min), and xip was significantly greater than +10 cm and Land (all $p < .001$). Land and +10 cm were not significantly different from each other. Interactions between water depth and treadmill speed on EE can be observed in Table 3.

Heart Rate

Similar to the responses that were observed for EE, heart rate was also influenced by water depth, with –10 cm (122.3 ± 25.0 beats/min) significantly greater than xip (115.9 ± 21.9 beats/min), +10 cm (106.9 ± 17.0 beats/min) and Land (108.9 ± 19.5 beats/min), and xip significantly greater than +10 cm and Land (all $p < .001$). Land and +10 cm were not significantly different from each other. Interactions between water depth and treadmill speed on HR can be observed in Table 4.

Table 3 Effect of Water Depth and Treadmill Speed on Energy Expenditure (kJ/min)

Water Depth	Speed (kph)					
	2.41	3.22	4.02	4.83	5.63	6.44
-10 cm	12.2 (2.3)^{a}	16.5 (3.8)^{a}	22.4 (4.1)^{a}	29.7 (4.8)^{a}	34.9 (5.1)^{a}	37.4 (4.6)^{a}
Xip	11.7 (2.0)^{ab}	15.5 (2.7)^{ab}	19.6 (3.0)^{ab}	25.0 (4.9)^{b}	29.1 (5.4)^{b}	32.3 (5.2)^{b}
+10 cm	10.8 (2.3)^{b}	14.4 (2.7)^{b}	17.0 (3.4)^{b}	20.0 (3.2)^{c}	23.4 (4.1)^{c}	26.2 (3.9)^{c}
Land	12.9 (2.9)^{a}	14.1 (3.0)^{b}	16.9 (3.5)^{b}	20.0 (4.8)^{c}	23.3 (5.9)^{c}	29.7 (7.8)^{bc}

Mean (SD). Same letters in a column are not significantly different from each other, $p < 0.05$

Table 4 Effect of Water Depth and Treadmill Speed on Heart Rate (Beats/min)

Water Depth	Speed (kph)					
	2.41	3.22	4.02	4.83	5.63	6.44
-10 cm	95.4 (13.4)	103.2 (14.1)^{a}	113.6 (12.5)^{a}	128.0 (17.2)^{a}	142.1(16.1)^{a}	151.6 (16.2)^{a}
Xip	94.0 (12.6)	99.6 (12.5)^{ab}	109.3 (12.6)^{ab}	121.8 (14.3)^{a}	132.4 (17.9)^{a}	139.3 (17.2)^{b}
+10 cm	89.0 (10.1)	95.6 (10.0)^{b}	103.4 (11.1)^{b}	110.3 (10.8)^{b}	118.1 (12.9)^{b}	125.2 (15.0)^{c}
Land	94.5 (12.4)	97.2 (12.8)^{b}	102.0 (12.3)^{b}	108.3 (13.6)^{b}	118.4 (16.7)^{b}	133.1 (17.9)^{bc}

Mean (SD). Same letters in a column are not significantly different from each other, $p < 0.05$

When the relationships between EE and BMI were plotted, a significant relationship existed between –10 cm (slope = 0.3094, $p < .05$) and Land (slope = 0.5988, $p < .05$), but not for xip (slope = 0.1586, $p > 0.20$) or +10 cm (slope = 0.0974, $p > 0.68$; Figure 1). HR was significantly related to EE for both Land ($r^2 = 0.55$, $p < .01$) and ATM ($r^2 = 0.69$, $p < .05$).

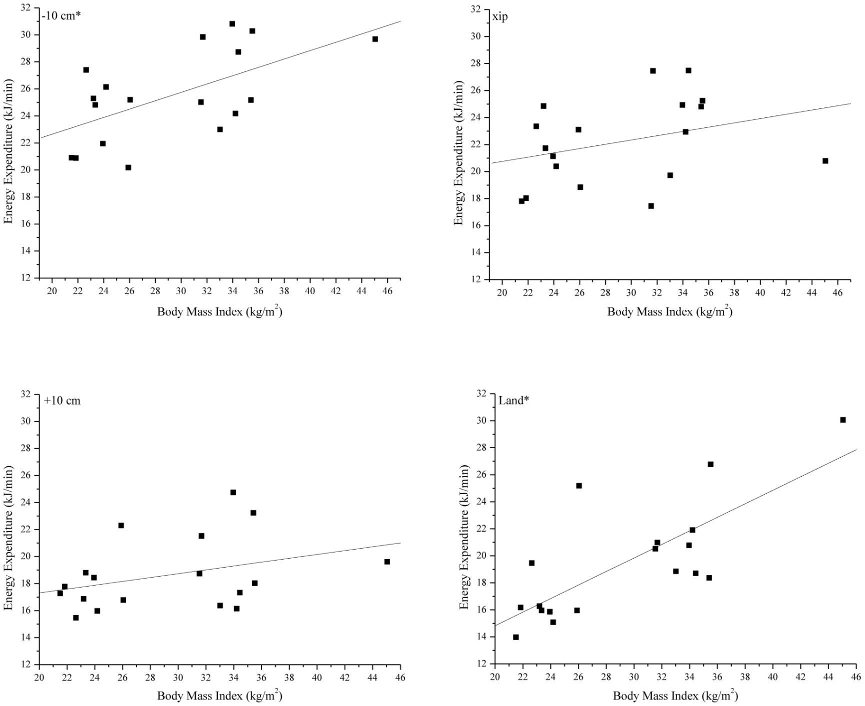

Figure 1 — Relationships between energy expenditure and body mass index (BMI) for each water depth. *p < .05

Ratings of Perceived Exertion

RPE-O for -10 cm (10.3 ± 3.19) was significantly different from xip (9.40 ± 2.66, $p < .001$), +10 cm (8.94 ± 2.35, $p < .0001$) and Land (8.48 ± 2.67, $p < .0001$), while xip was significantly different from Land ($p < .05$). RPE-L for -10 cm (10.6 ± 3.23) was significantly different from xip (9.78 ± 2.93, $p = .002$), +10 cm (9.14 ± 2.50, $p < .0001$) and Land (8.62 ± 2.86, $p < .0001$), while xip was significantly different from +10 cm ($p < .02$) and Land ($p = 0.001$). Interactions between water depth and treadmill speed on RPE-O and RPE-L can be observed in Figure 2.

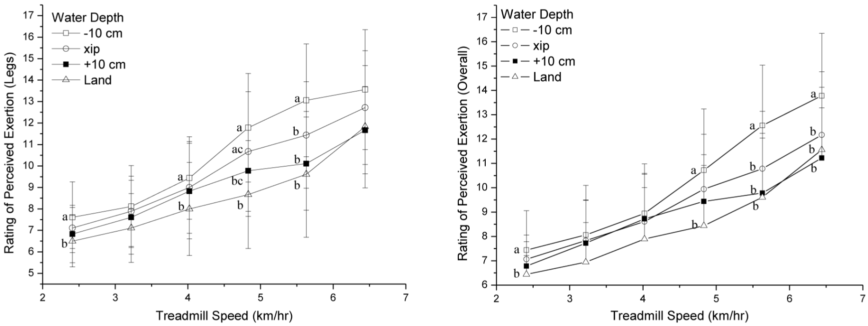

Figure 2 — Interactions between water depth and treadmill speed on RPE-O and RPE-L (Mean ± SD). Same letters in a column are not significantly different from each other, $p < .05$

Discussion

Influence of Water Depth

Our results confirm that relatively minor changes in water depth (±10 cm) significantly influence cardiorespiratory variables and a subject's perception of effort during walking on an aquatic treadmill (ATM). Heart rate, EE, and RPE increased significantly as water depth was lowered from a position 10 cm above xiphoid to xiphoid level and 10 cm below xiphoid level.

Previous research addressing water depth effect on cardiorespiratory parameters compared much greater differences in water depth (Gleim & Nicholas, 1989; Pohl & McNaughton, 2003). Gleim and Nicholas (1989) contrasted walking rapidly at 6.44 kph in water depths of ankle, patella, midthigh, and umbilicus. With the exception of the umbilicus depth, these depths present added resistance due to movement in water with essentially no buoyancy benefit when compared with land. Oxygen consumption and HR was significantly lower at umbilicus vs. midthigh and patella and similar to ankle depth. With a depth at the anterior superior iliac spine (ASIS), body weight is reduced by approximately 57% (Harrison, Hillman, & Bulstrode, 1992). In terms of stature, the ASIS is approximately the same height as the umbilicus. Pohl and McNaughton (2003) compared walking at 4.02 kph at umbilicus and midthigh deep water. VO_2 (20.2 vs. 17.5 ml/kg/min) and heart rate (104 vs. 96 bpm) were significantly greater for midthigh versus umbilicus.

Two walking speeds at the -10 cm water depth in the current study are similar to the conditions (speed and water depth) used in the Gleim and Nicholas (6.44 kph) and the Pohl and McNaughton (4.02 kph) studies. The average VO_2 while walking at 6.44 kph in Gleim and Nicholas' study was 26.0 vs. 23.0 ml/kg/min in the current study. At 4.02 kph, Pohl and McNaughton (2003) reported a VO_2 of 17.5 vs. 13.9 ml/kg/min in the current study. The lower values in the current study may be due to two factors. First, the water depth in both the Gleim and Nichols and Pohl and McNaughton studies were slightly below that of the current study (umbilicus vs. xiphoid).

Based on the findings of the current study, this discrepancy should account for the majority of differences in VO_2. Second, the subject characteristics may have been a factor. In the current study, one half of the subjects had a BMI greater than 30 kg/m^2. This likely contributed to a greater buoyancy effect thus decreasing EE in ATM.

The effect of water depth is evident even when exercise intensity is self-selected. When using a self-selected exercise intensity equivalent to an RPE rating of 13 in xiphoid depth water, HR was similar to land (Fujishima & Shimizu, 2003), whereas at axilla level HR was significantly lower in water than on land (Takeshima, Nakata, Kobayashi, Tanaka, & Pollock, 1997).

While exercising in water, there are two factors that influence the cardiorespiratory and energy expenditure response: (a) drag resistance of moving limbs through water and (b) a hydrostatic force supporting body weight in water (buoyancy). When buoyancy is inadequate to provide substantial limb unloading, as is typically seen in water levels below the waist (i.e., patella and midthigh), drag forces imposed by fluid resistance substantially elevate the metabolic cost, as evidenced by increased VO_2, VO_2 cost per stride and HR (Gleim & Nicholas, 1989; Pohl & McNaughton, 2003). Conversely, when water depth meets or exceeds waist height, increases in buoyancy counteract a concomitant increase in workload imposed by fluid resistance and metabolic cost declines.

Our results support these trends and extend current observations to water depths typically used for exercise and rehabilitative purposes (xiphoid or midchest water depths). The majority of studies, utilizing the ATM or Flowmill devices investigating the cardiorespiratory effects of water walking, have selected the xiphoid level (Fujishima & Shimizu, 2003; Hall et al., 1998; Hall, Grant, Blake, Taylor, & Garbutt, 2004; Masumoto, Shono, Hotta, & Fujishima, 2008; Masumoto et al., 2009; Shono et al., 2000; Shono, Fujishima, Hotta, Ogaki, & Masumoto, 2001; Shono, Fujishima, Hotta, Ogaki, & Ueda, 2001; Shono et al., 2007). Perhaps this depth is considered by investigators and rehabilitation specialists to be a water depth that "balances" the buoyancy effect of water, reducing the stress on lower extremity joints with the added EE required due to drag forces associated with moving in water. In a previous study in our laboratory we determined the xiphoid level allowed participants to maintain a running pattern that produced a similar EE on land versus water (Rutledge, Silvers, Browder, & Dolny, 2007). In contrast to previous research, we have demonstrated that water depth adjustments do not have to be as severe as previously investigated to significantly influence cardiorespiratory parameters.

Finally, water depth influenced the relationship between EE and BMI. On land, body weight significantly influences the absolute metabolic cost of walking (Lafortuna et al., 2008), similar to the relationship in ATM water depth of –10 cm; however, as water depth increased (xip and +10 cm), the magnitude of this relationship diminished. The buoyancy of subjects is determined by body composition (and indirectly BMI). The greater water depth increased the magnitude of buoyancy subjects experienced and removed to an extent the influence body weight has on the metabolic cost of walking. This suggests that to accurately prescribe ATM exercise intensity water depth must be taken into account.

Land vs. Water

In previous studies that compared walking on land vs. water, the level of the xiphoid has been the predominant depth selected (Hall, Grant, Blake, Taylor, & Garbutt

2004; Hall et al., 1998; Masumoto et al., 2008; Migita et al., 1994; Shono et al., 2000; Shono, Fujishima, Hotta, Ogaki, & Ueda 2001; Shono et al., 2007). At this depth, Hall and colleagues (1998) reported VO_2 was similar in land and water walking at 3.5 kph, but significantly greater in water compared with land at 4.5 and 5.5 kph. HR was lower in water than in land at 3.5 kph, and similar at 4.5 and 5.5 kph. Masumoto and colleagues (2008) evaluated older females (mean age = 62 yrs) and reported significantly greater values for VO_2 (16.0 vs. 10.8 ml/kg/min), HR (107 vs. 88 bpm), and RPE-L (11.4 vs. 9.6) while walking at 2.4 kph in water vs. land. Shono et al. (2007) reported a significantly greater VO_2 while walking in the Flowmill at the same velocity (2.4 kph) compared with land. Migita et al. (1994) demonstrated that to elicit a similar EE (VO_2) only one-half of the land walking speed is required while walking in the Flowmill against a water current equal to the speed of walking. Previous research utilizing the Flowmill has reported walking intensities up to 3.0 kph, similar to one of the speeds (3.22 kph) used in the current study. The average VO_2 of 9.73 ml/kg/min in this study is dramatically lower than what was reported by Shono et al. (2000) and Shono, Fujishima, Hotta, Ogaki & Masumoto (2001) of ~18 ml/kg/min. Interestingly, at 60% of that walking speed (1.8 kph) in the Flowmill of their study, VO_2 was very comparable (8.75–9.12 vs. 8.72 ml/kg/min) with the land condition in this study, supporting the contention of Migita et al. (1996) that the Flowmill places a significantly greater metabolic demand than land or water walking on a treadmill without a water current. While walking at the xyphoid level, the arms also swing against the resistive drag forces of water that likely contributes to a similar EE versus land despite the lower stride cadence.

HR-VO_2 Relationships

As expected HR, EE (VO_2), RPE-O, and RPE-L increased with treadmill speed in all conditions. These results support previous work utilizing both the ATM (Hall, Grant, Blake, Taylor & Garbutt 2004; Hall et al., 1998) and the Flowmill (Masumoto et al., 2008; Shono et al., 2000; Shono, Fujishima, Hotta, Ogaki, & Ueda 2001; Shono et al., 2007). When walking on land the VO_2-walking speed relationship is linear and ranges from $r^2 = 0.49–0.98$, while the HR-walking speed relationship ranges from $r^2 = 0.23–0.96$ (Masumoto et al., 2008; Shono et al., 2000; Shono, Fujishima, Hotta, Ogaki, & Ueda 2001; Shono et al., 2007). These values are comparable to the current study ($r^2 = 0.56$ for Land and 0.69 for ATM). In one study, the relationship between VO_2 and HR tended to be greater in water ($r^2 = 0.65$) compared with land ($r^2 = 0.45$), while walking at speeds ranging from 1.2–2.4 kph in water and 2.4–4.8 kph on land, respectively (Masumoto et al., 2008). Shono (Shono et al., 2000; Shono, Fujishima, Hotta, Ogaki, & Ueda 2001; Shono et al., 2007) has consistently reported a stronger relationship ($r^2 = 0.98$) between HR and VO_2 while walking between 1.2 and 3.0 kph in the Flowmill. In those studies the VO_2 vs. HR is a linear relationship while the VO_2 vs. speed and HR vs. speed were exponential.

Ratings of Perceived Exertion

The exercise bouts were well-tolerated by all participants. The faster speeds proved to be a challenge for several individual participants and were reflected by relatively high RPE-O and RPE-L, especially in the –10 cm condition at 6.42 kph where EE was greater than the other conditions. An average RPE-O score of 13.8 suggests that this workload was considered somewhat hard to hard (Borg, 1982) demonstrating the range of exercise intensities our subjects experienced during test conditions.

Masumoto and colleagues (2008) reported RPE-L was significantly greater in water vs. land due to the increased VO_2, HR, and greater percentage activation (%MVC) of four lower extremity muscles. Hall, Grant, Blake, Taylor, and Garbutt (2004) determined that RPE-L scores were similar while walking at slow speed (2.46 kph) but greater at 3.5 and 4.5 kph in rheumatoid arthritis patients. At slow speeds, drag forces are low but increase significantly with increases in walking speed. Based on the results of the current study, the similarity of HR and EE during walking on land and in water at identical speeds may be dependent upon the water depth selected. In support of the cardiorespiratory data were the self-reported perceived exertion of the subjects. Both RPE-O and RPE-L measures mirrored EE and HR, demonstrating that the change in exercise intensity due to water depth was evident. In this study, participants were not blinded to the depth of water they experienced each session. At the start of each session, the ATM floor was lowered to the appropriate water depth. Typically, the floor had to be adjusted slightly up or down to arrive at the exact water depth. The participants never received any information, suggesting one water depth would be easier or more difficult than another. Perhaps the relatively small differences in water depth were not as obvious to the participants. Once the exercise began, the movement in the water created small waves that likely obscured the true depth. In retrospect preventing the participants from observing the initial setting of the water depth would be preferred.

Considering the many disadvantages and the limitations that overweight individuals have including their high risk of injuries that could prevent them from continuing their walking program over time, it become apparent that the aquatic treadmill has advantages over the land treadmill for them (i.e., lower ground reaction forces). Recently a study confirmed that ATM training provided a comparable improvement in aerobic capacity with a greater increase in leg lean body mass in previously inactive, overweight, and obese adults (Greene et al., 2009). Perhaps this form of exercise training may also yield lower incidences of overuse injuries.

Conclusion

Our results demonstrate that small changes in water depth influences exercise EE, HR, and RPE in female exercise participants. These differences are likely attributed to a changing relationship between drag resistances and buoyancy in water. With the added buoyancy of deeper water, the normal relationship of EE and BMI during walking is compromised. These results suggest water depth can be used to selectively adjust exercise intensity during water walking. Therefore, substituting aquatic treadmill walking for land walking might be beneficial for overweight individuals as they strive to incorporate physical activity into their lifestyle.

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