Cardiorespiratory responses to aquatic treadmill walking in patients with rheumatoid arthritis

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ABSTRACT **Background and Purpose**. *Hydrotherapy is popular with patients with rheumatoid arthritis (RA). Its efficacy as an aerobic conditioning aid is equivocal. Patients with RA have reduced muscle strength and may be unable to achieve a walking speed commensurate with an aerobic training effect because the resistance to movement increases with speed in water. The physiological effects of immersion may alter the heart rate–oxygen consumption relationship (HR–*$\mathring{V}O_2$*) with the effect of rendering land-based exercise prescriptions inaccurate. The primary purpose of the present study was to compare the relationships between heart rate (HR), and ratings of perceived exertion (RPE), with speed during land and water treadmill walking in patients with RA.* **Method**. *The study design used a two-factor within-subjects model. Fifteen females with RA (47±8 SD years) completed three consecutive bouts of walking for five minutes at 2.5, 3.5 and 4.5 km/h*$^{-1}$ *on land and water treadmills. Expired gas, collected via open-circuit spirometry, HR and RPE were measured.* **Results**. *HR and RPE increased on land and in water as speed increased. Below 3.5 km/h*$^{-1}$ $\mathring{V}O_2$ *was significantly lower in water than on land (*$p<0.01$*). HR was lower (*$p<0.001$*), unchanged and higher (*$p<0.001$*) at 2.5, 3.5 and 4.5 km/h*$^{-1}$ *in water than on land. RPE was significantly higher in water than on land (*$p<0.05$*).* $\mathring{V}O_2$ *was approximately 60% of the predicted* $VO_{2\,max}$ *during the fast walking speed in water. For a given* $\mathring{V}O_2$*, HR was approximately nine beats/min*$^{-1}$ *and RPE 1–2 points on the 6–20 Borg scale, higher in water than on land.* **Conclusions**. *The study showed that the metabolic demand of walking at 4.5 km/h*$^{-1}$ *was sufficient to stimulate an increase in aerobic capacity. The use of land-based prescriptive norms would underestimate the metabolic cost in water. Therefore, in water HR should be increased by approximately 9 beats/min*$^{-1}$ *to achieve similar energy demands to land treadmill walking.*

Key words: aerobic capacity, exercise, water

INTRODUCTION

Rheumatoid arthritis (RA) is a chronic inflammatory disease of the synovial joints, characterized by swollen, painful joints, disturbed joint motion and muscle atrophy that results in physical deconditioning (Ekdahl and Broman, 1992). Improving aerobic capacity (VO_{2max}) through the use of hydrotherapy is popular but the evidence base is lacking because of the methodological defects of the few studies available (Daneskiold-Samsoe, 1987; Minor et al., 1989; Melton-Rogers et al., 1996; Sandford-Smith, 1998; Verhagen et al., 2000). Furthermore the evidence is equivocal, with Rintala et al. (1996), showing no changes in VO_{2max} after a 12-week hydrotherapy programme. This is likely to be related to the use of rate of perceived exertion (RPE) as the method of exercise prescription, in that exercise in water produces a greater perception of effort for a given $\mathring{V}O_2$ (Svedenhag and Seger, 1992; Hall et al., 1998). Therefore, it is possible that the use of land-based measures to monitor exercise intensity may have underestimated the aerobic demand. Melton-Rogers et al. (1996) showed that the intensity of deep water running in eight patients with RA provided sufficient stimulus for improvement of aerobic capacity as recommended by the American College of Sports Medicine (ACSM, 1991). However, it is unlikely that the majority of patients with RA would be capable of performing deep water running given that subjects are suspended in deep water and make no foot contact with the pool bottom. Furthermore, Moening et al. (1993) showed it has been shown that the biomechanical demands of deep water running are dissimilar from land running. Therefore, translation of any functional effects to dry land may be limited. A study on normal females who walked on a water treadmill showed that the cardiorespiratory stimulus was below that recommended by the ACSM for improvements in aerobic capacity because they were unable to walk fast enough against the resistance of the water. This finding was attributed to insufficient leg strength and implies that the cardiorespiratory challenge is limited by peripheral fatigue as a result of the resistance to movement in water as speed increases (Hall et al., 1996). At slow speeds in water, when resistance is minimal, buoyancy dominates and may result in reduced energy expenditure compared with similar speeds on land. As speed increases so does the resistance which may result in the preferential utilization of glycolytic, rather than aerobic pathways. There is therefore an interaction between buoyancy (at slow speed) and resistance (at fast speed) that could affect the metabolic pathways used and the ability of hydrotherapy to improve aerobic fitness. Patients with RA have reduced muscle strength and may be unable to generate the walking speeds in water that are required to stimulate a cardiorespiratory response of the magnitude recommended by the ACSM for improved aerobic fitness (ACSM, 1991). Therefore, the first aim of the present study was to determine if the cardiorespiratory system could be stimulated in line with ACSM recommendations for improvement in aerobic capacity during treadmill walking in water, as this type of functional activity is considered to mimic terrestrial gait most closely. The second aim of this study was compare the relationship between oxygen consumption ($\mathring{V}O_2$) to heart rate (HR) and ratings of perceived exertion (RPE) given the importance of these linear relationships in the monitoring of exercise intensity on land. These relationships may differ in water because of the hypervolaemia and enhanced cardiac output associated with head-out water immersion (Christie et al., 1990;

Gabrielsen et al., 2000). Furthermore, the literature on walking and running activities in water shows that the relationship is altered depending on the water temperature, water depth, exercise intensity, type of exercise and subject skill (Frangolias and Rhodes, 1996; Melton-Rogers et al., 1996; Hall et al., 2001). Therefore, the null hypothesis that the $\mathring{V}O_2$–HR and $\mathring{V}O_2$–RPE relationships were similar in water to land was tested.

METHOD

Study design

The study used a two-factor within-subjects design.

Subjects

Fifteen female patients, aged 30–60 years with functional Class I or Class II RA, according to the criteria of the American College of Rheumatology (Hochberg et al., 1992), and with a disease duration of five years or less were recruited from Royal National Hospital for Rheumatic Diseases, Bath. Patients with early disease were chosen to ensure completion of all the tasks required. Patients were excluded if they walked with an aid, had undergone lower limb surgery within the past three months, had undergone hip, knee or ankle arthroplasty or were experiencing a flare-up of their RA. Additionally, patients with known cardiovascular disease were excluded. Female patients were selected on the basis of greater female to male incidence of RA. Furthermore, data in the literature on the detraining effects associated with RA are generated primarily from female patients (Minor et al., 1988; Hakkinen et al., 1995). Patients meeting the entry criteria were identified from the database at the Royal National Hospital for Rheumatic Diseases, Bath, and were invited to participate in the study by letter.

The sample size was calculated using data from a previous study on normal females (Hall et al., 1998). By use of the differences in $\mathring{V}O_2$ between water and land treadmill walking as the dependent variable, power of 80% and alpha of 0.05 showed that a sample size of 15 patients was necessary.

Ethical approval

Ethical approval for the study was granted by the local regional ethical committee.

Protocol

At an initial visit, and following their informed, written consent, patients' past and current medical history was documented by means of a health screening questionnaire and an interview adapted from the Hydrotherapy Association of Chartered Physiotherapists Standards for Good Practice (Great Britain). Information on the level of habitual physical activity was recorded using the Allied Dunbar National Fitness Survey (Allied Dunbar National Fitness Survey, 1992). Details about disease duration and status, duration of early morning stiffness, medication, height, weight, HR, blood pressure (BP) and joint tenderness were recorded using the Ritchie Articular Index (Thompson et al., 1981). Disease status and pain were evaluated by use of the Health Assessment Questionnaire (Fries et al., 1980) and visual analogue scale (VAS) (Scott and Huskisson, 1976).

Following these procedures patients underwent a familiarization period in the water (Aquaciser 100R, Ferno UK) and on the land treadmills (Trimline 4000T). A pilot study ascertained that patients required 30 minutes' instruction and practice on the water treadmill to feel comfortable and be consistent in their technique. Practising land treadmill walking required 10 minutes. The first visit therefore lasted approximately 2.5 hours. Given the novelty of walking with a mouthpiece *in situ* it was considered important for patients to experience this before data collection periods, and patients returned to the Aquaciser laboratory for a further 30-minute visit to become comfortable with the open-circuit spirometry set-up during land and water treadmill walking. Patients were also instructed in the use of the Borg scale.

A pilot study indicated that patients were able to walk on the water treadmill at speeds up to a maximum of 4.5 km/h^{-1}. Above this speed patients were forced to run or hold on to the handrails. Therefore three speeds of walking were selected: 2.5, 3.5 and 4.5 km/h^{-1}, representing slow, moderate and fast. During the water treadmill test patients were instructed to walk 'as normally as possible' without holding on to the handrails. To prevent sculling-type motions of the hands, patients were asked to adopt a loose-fisted position with the forearm in mid-prone and the elbow flexed to 90˚. After a two-minute warm-up period patients completed three consecutive bouts of five minutes' duration at progressively increasing speeds (2.5, 3.5 and 4.5 km/h^{-1}). Use of the water treadmill enabled the water depth to be made individual to the level of the xiphoid process, and the water was maintained at thermoneutral (34.5 ˚C) as recommended by the Hydrotherapy Association of Chartered Physiotherapists. The land and water tests were performed in random order at the same time of day and separated by at least 72 hours. Patients were two hours post-prandial and refrained from smoking and caffeine intake from two hours before the test began. Patients were reminded to continue with their usual medication regimen, especially in respect of time of ingestion on the days testing took place. Speed and gradient calibration checks on both treadmills were made at monthly intervals. The air temperature of the laboratory averaged 26˚C (±2.1˚C) and the humidity was 50% (±4.8%).

Measurements

Expired gas was collected for the final minute of each exercise bout via open-circuit spirometry by use of a Hans–Rudolph valve, mouthpiece and Douglas bag system, and following the technique described by Cooke (1996). Gas samples were analysed using an infrared CO_2 analyser (PK Morgan 901, Gillingham, UK) and a paramagnetic O_2 analyser (OA 250 Servomex). The respiratory exchange ratio (RER) was calculated from $\mathring{V}OC_2/\mathring{V}O_2$. Ventilation ($\mathring{V}_E$) was recorded using a dry gas volume meter (Havard Apparatus, UK). Gas volumes were corrected to standard conditions of temperature, pressure and dry (STPD) and standard calculations were used to calculate $\mathring{V}O_2$, $\mathring{V}_E$ and $\mathring{V}CO_2$ (Powers and Howley, 2001). Stride frequency was recorded for 60 s in the fourth minute of each exercise bout by counting the number of strides. In the final 10 s HR was measured by use of a short range telemetry device (Polar Favor™ HR monitors) and RPE using the Borg 6–20 scale, which has been shown to be a reliable and valid instrument to measure perceived exertion (Noble and Robertson, 1996). Two scales were completed after the method adopted by Svedenhag and Seger (1992): one for the legs (RPEL) and one for breathing (RPEB), representing peripheral muscle and respiratory–metabolic signals, respectively. Standardized verbal and written instructions for completing the RPE scales were given to subjects during the familiarization period and before each walking test. BP was recorded using a manual sphygmomanometer on the following occasions:

- Standing on land before exercise.
- Standing immersed on the water treadmill immediately before exercise.
- Immediately exercise finished.
- Five and ten minutes after the end of exercise whilst standing on land.

Because it was not possible to make measurements of core body temperature, sub-lingual temperature was recorded before and after the exercise session. After the water treadmill test only it increased significantly by 0.37 ˚C (p<0.004).

Data analysis

Exploratory data analysis included examination of descriptive statistics for outliers, skewness and kurtosis; completion of the Kolmogorov–Smirnov to test normality of distribution were performed. A two-way analysis of variance (ANOVA) with repeated measures was used to examine differences between land and water walking and speed. When significant F values of p<0.05 were found, post hoc testing using paired Student's t-tests with a Bonferroni correction factor were employed to isolate the significant differences (Kinnear and Gray, 1999). The Friedman test was used to examine differences in RPE data. This was followed up by the Wilcoxon test and Bonferroni correction factor when an overall significant p value was observed. Pre- and post-test data (e.g. oral temperature and BP) were analysed using paired Student's t-tests. Differences between relationships were tested by use of a paired Student's t-test after a simple linear regression model estimated the dependent variable, for a given level of the independent for each patient, and tests for normality of the response variable were satisfactory. All values are expressed as mean ± standard deviation (SD). Data was analysed using *SPSS for Windows*, Version 10.

RESULTS

Fifteen female patients (average age 47 years: SD ±8.05 years), height 1.62 m (SD ±0.06 m), weight 63.4 kg (SD ±8.85 kg), body mass index (BMI) of 24 (SD ±3.2) and disease duration of 3.1 years (SD ±1.3; range 1–5 years) completed the study. Table 1 shows other important characteristics of the study population.

Fourteen patients belonged to functional Class II and one to functional Class I (Hochberg et al., 1992). Levels of habitual physical activity were low (median = one; range = one to three) as assessed by the Allied Dunbar National Fitness Survey (1992). Resting HR, taken before rising in the morning averaged 71 beats/min^{-1} (±8.6 beats/min^{-1}), and standing BP averaged 119/84 mmHg. Four patients smoked (range 3–20 cigarettes/day) and three had asthma, controlled by inhalers. One patient took thyroxine for hypothyroidism. All patients

TABLE 1: Sample characteristics of study population

	Duration of early morning stiffness (min)	*Health Assessment Questionnaire*	*Ritchie Index*	*Pain (10 cm VAS)*
Median	5	0.125	8	1.1
Interquartile range	0–5	0–1.625	2–28	0.1–39

VAS: Visual analogue scale.

were on disease-modifying antirheumatic drugs and anti-inflammatory agents, the dose of which remained unchanged during the study.

As the treadmill speed increased $\dot{V}O_2$, $\dot{V}_E$ and $\dot{V}CO_2$ increased on both land and water treadmills ($p<0.001$). In each case, water treadmill responses were lower for $\dot{V}O_2$, $\dot{V}_E$ and $\dot{V}CO_2$ at 2.5 and 3.5 km/h^{-1} ($p<0.005$). At 4.5 km/h^{-1} there was no difference between $\dot{V}O_2$, $\dot{V}_E$ and $\dot{V}CO_2$ between the two conditions, as the response to water treadmill exercise increased to equate that on land. Figure 1 shows the relationship between $\dot{V}O_2$ and treadmill speed for land and water treadmill exercise. Figure 2 shows the $\dot{V}_E$–$\dot{V}O_2$ relationship, the range of which extended during water treadmill exercise. $\dot{V}_E$ did not differ significantly in water for a given $\dot{V}O_2$. During land treadmill walking the expected linear relationship between $\dot{V}_E$ and $\dot{V}O_2$ is seen. On land, the RER increased with speed ($p<0.01$). In water, the RER was similar at 2.5 and 3.5 km/h^{-1}, but increased significantly at 4.5 km/h^{-1}. No significant differences in RER were observed between the land and water treadmills (Table 2).

HR increased significantly on land and in water as the treadmill speed increased ($p<0.001$). On land, HR increased linearly but in water showed a significant interaction effect (Figure 3). At 2.5 km/h^{-1} HR was significantly lower in water than on land; it was similar at 3.5 km/h^{-1} and higher at 4.5 km/h^{-1} (p<0.001, NS and 0.001, respectively).

Figure 4 shows the relationship between HR and $\dot{V}O_2$ during land and water treadmill exercise. For the same speeds the range of response is extended in water and the line is shifted to the left. Thus, for a $\dot{V}O_2$ of approximately 0.74 L/min^{-1} HR was 9 beats/min^{-1} higher in water than on land ($p<0.002$). Conversely, land-based HR overestimates water $\dot{V}O_2$ by approximately 15%.

Systolic BP increased significantly with exercise on land and in water ($p=0.001$), but was unaffected by water immersion (Table 3). Diastolic BP was significantly reduced by water immersion ($p=0.004$), but was not affected by exercise. Consequently, mean

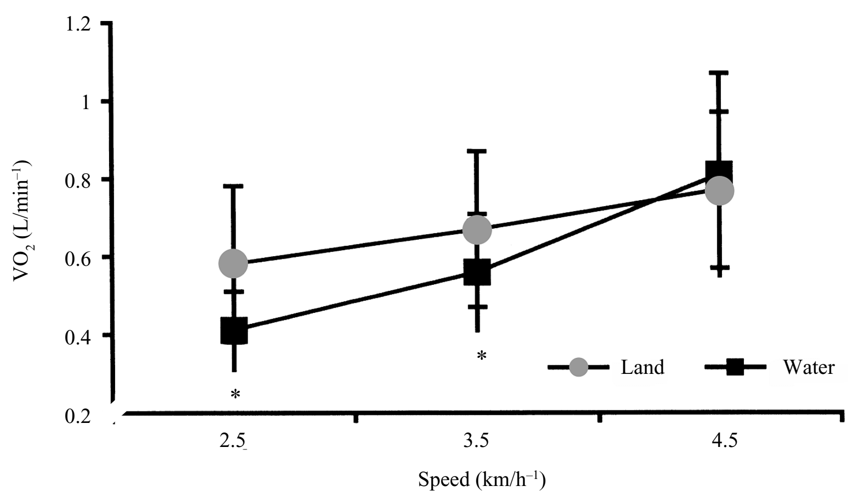

FIGURE 1: $\dot{V}O_2$ during land and water treadmill walking. As speed increased on land and in water, $\dot{V}O_2$ increased ($p<0.001$). *$p<0.01$; $\dot{V}O_2$ was significantly lower in water.

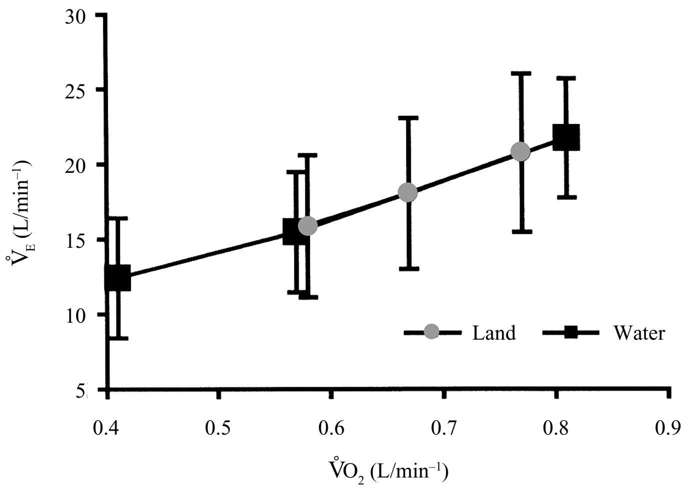

FIGURE 2: $\mathring{V}_E$–$\mathring{V}O_2$ relationship during land and water treadmill walking. $\mathring{V}_E$ did not differ significantly in water and on land for a given $\mathring{V}O_2$. However, the range is extended in water there is a greater percentage increase in $\mathring{V}_E$ relative to $\mathring{V}O_2$, especially at 4.5 km/h^{-1}.

TABLE 2: Means (SD) for respiratory exchange ratio (RER), ratings perceived exertion for breathing (RPE) and oxygen cost per stride ($\mathring{V}O_2$/str : mL/min^{-1})

Variable	*Water speed (km/h^{-1})*			*Land (km/h^{-1})*		
	2.5	3.5	4.5	2.5	3.5	4.5
RER	0.83 (0.1)	0.86 (0.1)	0.95** (0.08)	0.86 (0.07)	0.9* (0.07)	0.92* (0.07)
RPE–breathing	8.78 (1.6)	10.9* (1.6)	12.8** (2.1)	8.87 (2)	10.4* (1.9)	11.53** (2)
VO_2/str	5.9 (1.5)	7.04* (2)	8.9**^ (2.9)	6.45 (2.1)	6.42** (1.9)	6.92** (1.9)

* 3.5 km/h^{-1} is significantly greater then 2.5 km/h^{-1} within conditions (p <0.05).
** 4.5 km/h^{-1} is significantly greater then 2.5 km/h^{-1} within conditions (p <0.05).
^ The $\mathring{V}O_2$/stride is greater in water than on land at 4.5 km/h^{-1} (p <0.001).

arterial pressure (MAP) was lower during upright rest in water (p=0.002). No significant differences in MAP change were noted between land and water. Pulse pressure increased significantly with exercise on land and in water (p=0.001), but was not affected by water immersion.

A significant increase in RPEL with speed was observed during both land and water treadmill walking (p<0.001) (Figure 5). At 2.5 km/h^{-1} RPEL was similar between land and water conditions; above this speed the perception of effort was significantly greater in water than on land (p<0.012). Figure 6 shows the relationship between RPEL and $\mathring{V}O_2$, and shows that RPEL is higher for a given $\mathring{V}O_2$ in water by approximately 15–20% ($p\leq0.02$). For example, a RPEL rating of 12 gave rise to a $\mathring{V}O_2$ of 0.76 L/min^{-1} on land and 0.62 L/min^{-1} in water. Table 2 presents the results for RPEB as a function of speed. RPEB increased with speed during land and water treadmill walking (p<0.001). However, no significant differences in RPEB were observed between land and water exercise.

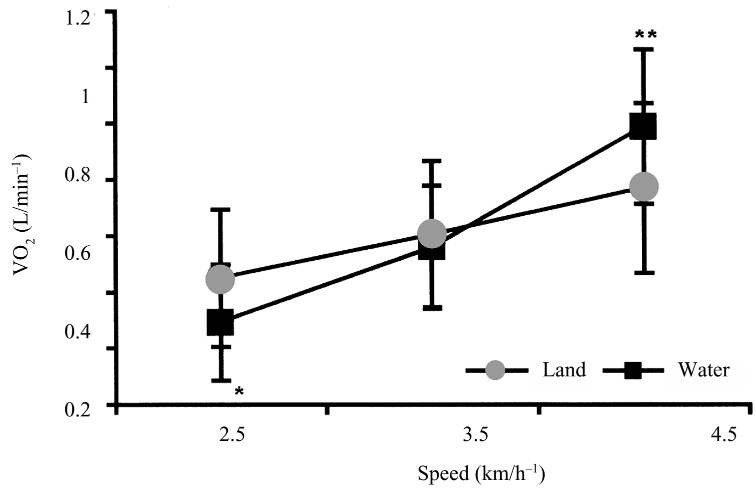

FIGURE 3: Heart rate during land and water treadmill walking. As speed increased on land and water, heart rate increased significantly (p<0.001). *p<0.01 = heart rate was lower in water than on land; **p<0.001 = heart rate was higher in water than on land.

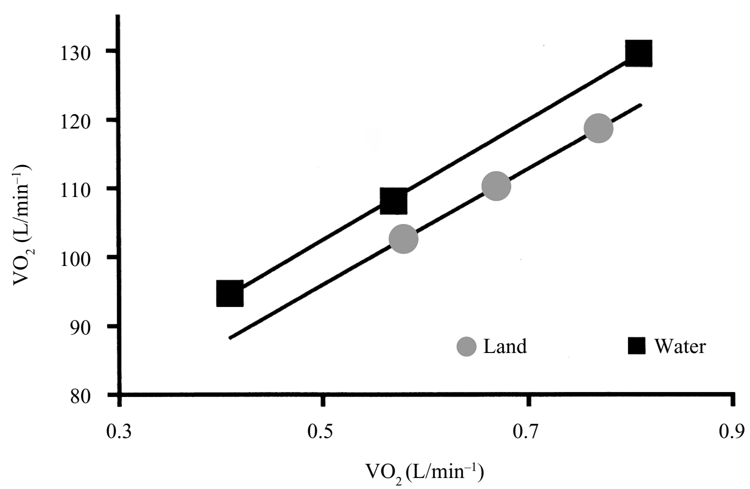

FIGURE 4: HR–$\mathring{V}O_2$ relationship. Heart rate (HR) was significantly higher in water than on land for a given $\mathring{V}O_2$ (p<0.003).

Figure 7 shows that cadence increased significantly with speed during land and water treadmill walking (p<0.001). However, at all speeds, stride frequency was approximately 21.9 strides/min^{-1} lower in water than land (p<0.001). Therefore, at 4.5 km/h^{-1} the oxygen cost per stride was significantly higher in water than on land (p<0.001) (Table 2).

TABLE 3: Mean (±SD) systolic and diastolic blood pressure, mean arterial pressure and pulse pressure before exercise, resting in water before exercise and immediately after exercise on land and in water (mmHG)

	Land	*Water*
Systolic BP		
Before exercise—standing on land	113.33 (15.6)	116.7 (15.5)
Before exercise—standing in water		113 (16)
After exercise	129.6 (18.3)*	126 (13.6)*
Diastolic BP		
Before exercise—standing on land	79.3 (11.8)	81.3 (9)
Before exercise—standing in water		71.2 (13.3)**
After exercise	80.5 (11.7)	67.6 (10.8)
Mean arterial pressure		
Before exercise—standing on land	90.7 (12.5)	93.1 (10.3)
Before exercise—standing in water		85.1 (11.5)***
After exercise	96.9 (12.9)	87.1 (8.4)
Pulse pressure		
Before exercise—standing on land	34 (8.6)	35.3 (11.2)
Before exercise—standing in water		41.8 (17.9)
After exercise	49.1 (12.4)†	58.4 (17.6)†

* Systolic blood pressure increased significantly with exercise whether on land or in water (Student's t-test = –5.7 and –5.3, respectively; df = 14; $p = 0.001$).
** Diastolic blood pressure was significantly reduced by water immersion (Student's t-test = 3.4; df = 14; $p = 0.004$).
*** Mean arterial pressure was significantly reduces by water immersion (Student's t-test = 3.8; df = 14; $p = 0.002$).
† Pulse pressure increased significantly with exercise on land and in water (Student's t-test = –56.2 and 6.8, respectively; df = 14; $p = 0.001$).

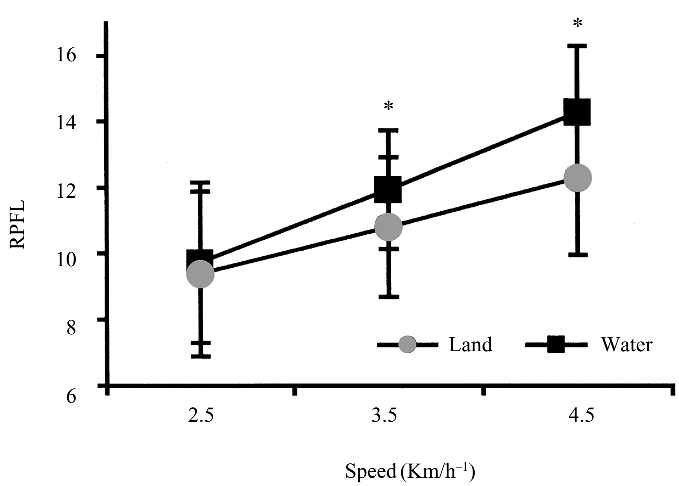

FIGURE 5: Rate of perceived exertion — legs (RPEL) during land and water treadmill walking. As speed increased on land and in water RPEL increased ($p<0.05$). *$p<0.05$; RPEL was significantly higher in water.

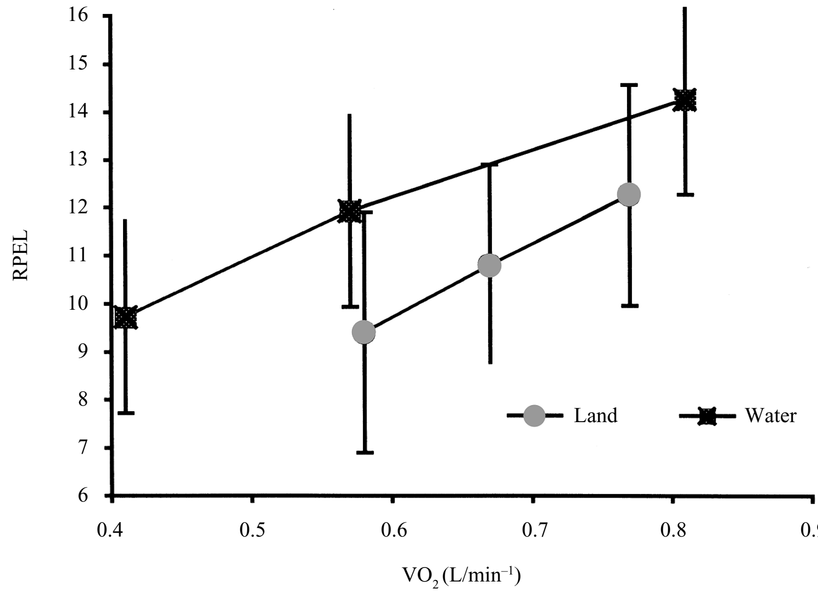

FIGURE 6: RPEL–$\dot{V}O_2$ relationship. Rate of perceived exertion (RPE) is approximately 15–20% higher in water than on land during treadmill walking (p<0.02).

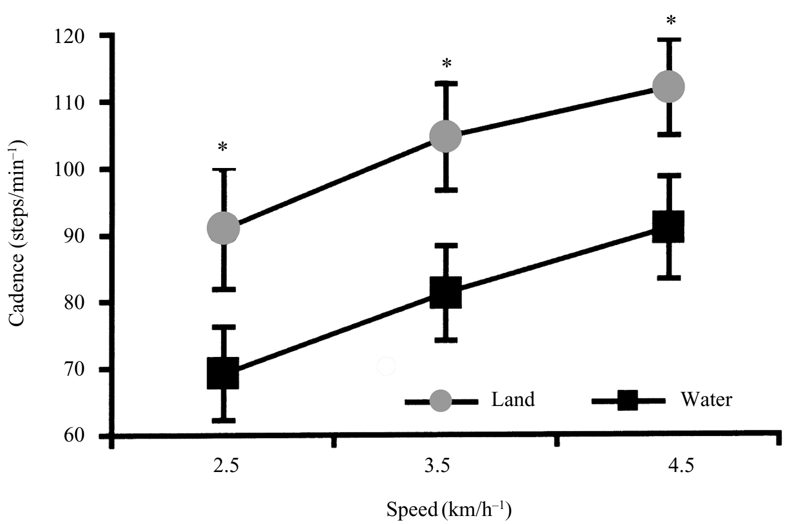

FIGURE 7: Cadence during land and water treadmill walking. As speed increased on land and in water, cadence increased (p<0.001). *p<0.001; cadence was significantly greater in water than on land.

DISCUSSION

The metabolic demands of walking in chest-deep thermoneutral water altered, depending on speed. At 2.5 km/h^{-1} $\dot{V}O_2$ and HR were lower in water than on land. Lower levels of $\dot{V}O_2$ suggest that resistance to movement is minimal and buoyancy effects dominate, causing a lower metabolic demand than on land. Muscle activity during slow movement is less in water than on land and this may account for both the lower HR and $\dot{V}O_2$ at 2.5 km/h^{-1} (Kelly et al., 2000). Furthermore, the exercise intensity at 2.5 km/h^{-1} was low and so the lower HR may be a consequence of the cephalad redistribution of blood during HOWI (head-out water immersion), which increases stroke volume with slight decrements in HR (Weston et al., 1987). At 3.5 km/h^{-1} $\dot{V}O_2$ was lower in water and HR similar to land walking, suggesting that the effects of exercise were beginning to supersede the effects of HOWI. A lower $\dot{V}O_2$ at this speed differs from previous reports that have shown similar (Hall et al., 1998) and higher values (Gleim and Nicholas, 1989) during water treadmill walking. These results vary from the present data and may be a consequence of differences in water depth and subject characteristics. The effects of buoyancy on percentage weight-bearing in women have shown that immersion to the xiphoid process unloads the lower limbs by 72%, resulting in only one-third of the body weight being transmitted to the ground (Harrison and Bulstrode, 1987). Immersion to the anterior superior iliac spines produced a percentage weight-bearing of 47%. Therefore, it is plausible that differences between waist- and chest-depth immersion could alter the metabolic demand of exercise in water because buoyancy supports the body weight and reduces postural muscle activity (Sugajimo et al., 1996). At 4.5 km/h^{-1} $\dot{V}O_2$ in water was similar to land and HR higher. Higher $\dot{V}O_2$ has been noted at this speed, suggesting that the effects of buoyancy are superseded by the greater resistance to movement as speed increases (Gleim and Nicholas, 1989; Hall et al., 1998). However, the similar $\dot{V}O_2$ between water and land treadmill walking presented here suggest that effect of buoyancy, although less than at slower speeds, was still evident.

In water, at rest, systolic BP was similar to land, but diastolic BP was lower by approximately 10 mmHg, which confirms other reports (Weston et al., 1987; Sramek et al., 2000). Similar increases in systolic BP after land and water exercise were observed and corroborate with data from other studies on exercise in water, albeit cycle ergometry in water (Christie et al., 1990; Sheldahl et al., 1992; Hanna et al., 1993). This finding suggests that the cardiovascular adjustments during dynamic exercise were not changed by water immersion, despite the assumed increase in cardiac output.

One of the aims of the present study was to determine if the cardiorespiratory system could be stimulated in line with ACSM recommendations for improvement in aerobic capacity (40–85% VO_{2max}, 55–90% HR_{max}, 12–16 on the 6–20 Borg RPE scale). Because it was not possible to perform maximal tests of aerobic capacity in the sample, the data were compared with those of other studies to estimate VO_{2max}. It is known that within four years of diagnosis aerobic capacity is 25–30% lower in patients with RA compared with age- and sex-matched control subjects, and Ekdahl and Broman (1992) reported VO_{2max} values between 1.24 L/min^{-1} and 1.47 L/min^{-1} in 43 women with RA aged between 23 and 65 years (Ekblom et al., 1974; Beals et al., 1985; Melton-Rogers et al., 1996; Minor et al., 1988). Comparing these data with data presented here suggests that walking at 4.5 km/h^{-1} in water required 55–65% of VO_{2max}. At the same speed in water, HR ranged from 55% to 75% of the predicted maximal heart rate (PMHR) and RPEL scored 14 at 4.5 km/h^{-1}. Although it is acknowledged that the use of normative data for VO_{2max} introduces a degree of error (most likely underestimating VO_{2max} in the present study sample given the relatively young age of participants and short disease duration), it is considered that that the range of exercise intensity at 4.5 km/h^{-1} was high enough to stimulate an aerobic response in all subjects.

Whether walking at 4.5 km/h^{-1} on a water treadmill for the recommended duration of 15–60 minutes three to five times a week for at least six weeks will result in the anticipated gains in aerobic capacity was outside the scope of the present study. Anecdotal evidence, based on patients' perceptions, suggested that some patients would have tired before the minimum time period elapsed. Therefore, an interval-type training method may be the most efficacious way of improving aerobic capacity in patients with RA.

The patients in the present study could be considered as a relatively homogenous subset of the larger RA population, in that they were young and with a disease duration of five years or less. Generalization of the study results to older patients of longer disease duration is not possible, but given that older patients with longer disease duration may have a greater degree of deconditioning than younger patients with short disease duration, it may be postulated that the latter may be unable to generate the required walking speeds to stimulate an aerobic response because of the resistance of the water. Research is required to support this theory.

A second aim of the present study was to compare the relationship of $\mathring{V}O_2$ to HR and RPEL, respectively, between water and land. Similar relationships between the two environments would suggest that the use of land-based HR or RPEL values to predict exercise intensity would be accurate in water. However, the results showed that HR was higher by approximately 9 beats/min^{-1}, and RPEL by 1–2 points, for a given $\mathring{V}O_2$ in water than on land. This means that the use of land-based values would underestimate metabolic demand in water. To ensure similar exercise intensity to land these data suggest that HR and RPEL values be increased by approximately 9 beats/min^{-1} and by 1–2 points, respectively.

A higher HR for a given $\mathring{V}O_2$ in water may be a thermal response, but, notwithstanding the significant 0.37°C rise in sublingual temperature, this is considered unlikely as the water was approximately thermoneutral, the exercise intensity was moderate and the duration short. A more appealing theory relates to the unfamiliar biomechanical demands of walking against the resistance of the water, which makes it difficult to generate the limb speeds observed on land. The present study confirms previous reports that stride frequency is significantly lower in water (by approximately 30%) and a lower cadence implies longer contraction times, which may result in reduced oxygen delivery and greater reliance on anaerobic pathways (Yu et al., 1994; Frangolais et al., 1996; Hall et al., 1998; Hall et al., 2001). Anaerobiosis implies preferential Type II muscle fibre recruitment, with consequent increased metabolic activation of the chemoreceptors in the active muscles, which augments sympathetic nervous activity and hence HR. Preferential Type II muscle fibre activation is also suggested by the greater percentage increases in $\mathring{V}_E$ relative to $\mathring{V}O_2$ in water when compared with land, although further research in which the speed increments are extended is recommended to examine the linearity of response. As subjects were utilizing approximately 60% of VO_{2max} at 4.5 km/h^{-1}, with a RPE of 14, it is possible that the ventilatory threshold had been reached. Furthermore, the RER was 0.95, suggesting that more carbohydrate than fat was metabolized. The shift from fat to carbohydrate metabolism occurs, in part, because of the recruitment of fast muscle fibres, which may be activated in response to the increasing resistance as speed increases in water.

A higher RPEL for a given $\dot{V}O_2$ in water than on land has been reported, and its implications for exercise prescription have been discussed (Svedenhag and Seger, 1992; Hall et al., 1998). A greater perceived exertion ties in with the theory forwarded for the similar greater increases in HR for given $\dot{V}O_2$. This disparity between perceived effort and physiological cost has been observed in other studies (Svedenhag and Seger, 1992; Hall et al., 1998). In the present study, RPE was divided into central and peripheral signals by asking patients to complete the scale with reference to their perception of effort for both breathing and legs, respectively. At 3.5 km/h^{-1} and at 4.5 km/h^{-1}, RPEL was higher in water than on land but RPEB was similar between conditions and speeds. This suggests that the limiting factor was local rather than central fatigue, and implies that the cardiorespiratory challenge was curtailed by the lack of peripheral muscle strength. Thus patients with RA who have strength deficits may take longer to achieve similar $\dot{V}O_2$ improvements compared with those without muscle atrophy.

IMPLICATIONS

Accepted wisdom states that appropriate hydrotherapy improves aerobic capacity in patients with RA. The present study has shown that energy expenditure is linked to velocity, which in turn is linked with leg muscle strength because of the increasing resistance in water as speed of movement increases. In our relatively homogenous population the ACSM recommendations for increasing aerobic fitness were met when walking at 4.5 km/h^{-1}. However, it was outside the scope of the study to examine the duration at which 4.5 km/h^{-1} could be correctly maintained; anecdotal reports suggested that an extended training period may be required before the minimum recommended course of 15 minutes could be achieved. Furthermore it is postulated that older patients with longer disease duration may be unable to elicit an aerobic response because the peripheral challenge supercedes the central one. Future research, utilizing accurate exercise prescriptions for water exercise and conforming to the demands of rigorous research designs, is required to test the hypothesis that hydrotherapy provokes increased aerobic capacity in patients with RA.

In clinical terms the study showed that prescribing and monitoring exercise intensity based on land-derived values of HR or RPEL during water treadmill walking in patients with RA will underestimate exercise intensity. Therefore it is recommended that land-based HR and RPEL should be increased by 9 beats/min^{-1} and by 1–2 points on the Borg 6–20 scale, respectively. However, hydrotherapists should be aware that the results of the study may not translate across to other forms of water activity because of biomechanical differences. Walking on a water treadmill is considered, biomechanically, to mimic terrestrial gait most closely when compared with other forms of walking and running in water. For example, it differs from shallow-water walking, during which subjects traverse the pool using a heel–toe gait pattern, in terms of reduced frontal resistance and therefore encourages a normal posture. It may therefore afford the best opportunity for transference of skills from water to land. However, the scarcity of water treadmills makes shallow-water walking the nearest alternative and it would be useful to replicate this study in shallow water.

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