ORIGINAL ARTICLE

Cardiocirculatory and metabolic responses at different walking intensities

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Objectives: Although walking is a common physical activity, scientifically based training guidelines using standardised tests have not been established. Therefore this explorative study investigated the cardiovascular and metabolic load resulting from different walking intensities derived from maximal velocity (V_{max}) during an incremental treadmill walking test.

Methods: Oxygen uptake, heart rate (HR), blood concentrations of lactate and catecholamines, and rating of perceived exertion were recorded in 16 recreational athletes (mean (SD) age 53 (9) years) during three 30 minute walking trials at 70%, 80%, and 90% of V_{max} (V_{70}, V_{80}, and V_{90}) attained during an incremental treadmill walking test.

Results: Mean (SD) oxygen uptake was 18.2 (2.3), 22.3 (3.1), and 29.3 (5.0) ml/min/kg at V_{70}, V_{80}, and V_{90} respectively ($p<0.001$). V_{70} led to a mean HR of 110 (9) beats/min (66% HR_{max}), V_{80} to 124 (9) beats/min (75% HR_{max}), and V_{90} to 152 (13) beats/min (93% HR_{max}) ($p<0.001$). Mean (SD) lactate concentrations were 1.1 (0.2), 1.8 (0.6), and 3.9 (2.0) mmol/l at V_{70}, V_{80}, and V_{90} respectively ($p<0.001$). There were no significant differences between catecholamine concentrations at the different intensities. Rating of perceived exertion was 10 (2) at V_{70}, 12 (2) at V_{80}, and 15 (2) at V_{90}. Twelve subjects reported muscular complaints during exercise at V_{90} but not at V_{70} and V_{80}.

Conclusions: Intensity and heart rate prescriptions for walking training can be derived from an incremental treadmill walking test. The cardiovascular and metabolic reactions observed suggest that V_{80} is the most efficient workload for training in recreational athletes. Further studies are needed to confirm these findings.

Over the last few decades, walking has been established as one form of endurance training for preventive purposes. Sufficient training effects with little risk of overstrain have been suggested.[1–4] Data on appropriate training intensities for walking vary in the literature, and published test procedures only partly allow training recommendations to be derived. With regard to intensity, many authors refer to maximal heart rate or maximal oxygen uptake.[5–7] For efficient cardiocirculatory training, the American College of Sports Medicine (ACSM) recommends 55/65–90% of maximal heart rate (HR_{max}) or 40/50–85% of maximal oxygen uptake reserve ($\dot{V}O_{2R}$) or HR_{max} reserve (HR_R).[8] However, approaches that use an incremental treadmill walking test (ITWT) as the basis for individual training recommendations are rare.[9–11]

The purpose of this study was to check whether an ITWT is applicable for the derivation of individual training recommendations. A secondary aim was to investigate if walking allows middle aged people to reach sufficient training intensity at comfortable speeds.

METHODS

This study was approved by the institution's review board and complies with the Declaration of Helsinki. Each participant gave written informed consent.

Subjects

Sixteen healthy subjects (10 men, six women) took part in the study. Their mean (SD) age was 53 (9) years, height 169 (8) cm, and weight 67 (11) kg. They were familiar with the walking technique and had been participating in recreational sport for an average of 34 months. Mean (SD) P_{max} obtained from an incremental cycling test was 2.6 (0.6) W/kg.

Study design

Firstly, all subjects had a clinical and laboratory routine examination and performed an incremental cycling test to rule out any health risks. Two to seven days later an ITWT was conducted followed by three walking tests at constant velocities: 70%, 80%, and 90% of the maximal velocity (V_{max}) obtained during the ITWT. Figure 1 shows the course of the study. The test period ranged between two and four weeks for each subject. The participants were told to neither change their normal training load during the study nor perform intensive or prolonged physical exercise on the day before the tests.

ITWT

One ITWT was performed for training purposes two to seven days before the second ITWT which served as the basis for the later tests of constant velocity. Starting at 4.3 km/h, the velocity was increased by 0.7 km/h every three minutes until exhaustion or V_{max} was reached with the appropriate walking technique (no race walking or running). The test was carried out without treadmill inclination to simulate as close as possible walking in the field. After two to seven days, a second identical ITWT was performed. During these tests, HR was measured and recorded continuously with a portable device (Accurex-Plus; Polar, Kempele, Finland). For the determination of the blood lactate concentration (Super GL; Greiner, Flacht, Germany), capillary blood was taken from the hyperaemised earlobe at rest and after each stage during a break of about 20 seconds. From the lactate curve, the individual anaerobic threshold (IAT) was determined by the

Abbreviations: HR, heart rate; IAT, individual anaerobic threshold; ITWT, incremental treadmill walking test; RPE, rating of perceived exertion; $\dot{V}O_2$, oxygen uptake

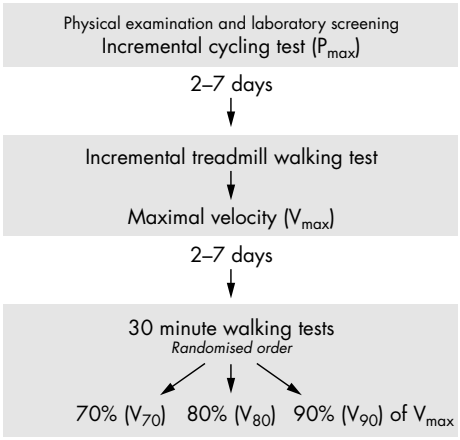

Figure 1 Overview of the study design.

method of Hagberg and Coyle,[12] which was evaluated with race walkers. For the radioenzymatic determination of catecholamines[13] before and immediately after exercise, 300 µl arterialised capillary blood was taken from the hyperaemized earlobe. In addition, gas exchange parameters (Meta-Max; Cortex, Leipzig, Germany) were continuously measured, and the rating of perceived exertion (RPE) recorded.[14]

With reference to V_{max}, individual intensities for three constant velocity exercises were determined (70%, 80%, and 90% of V_{max} = V_{70}, V_{80}, and V_{90}).

Walking endurance exercises

The subjects walked at the three intensities (V_{70}, V_{80}, and V_{90}) on the same treadmill for 30 minutes in random order. Before the 30 minute exercise, each subject walked for three minutes at V_{70} to warm up. During the exercise and for three minutes after it had finished, HR and oxygen uptake ($\dot{V}O_2$) were continuously measured. With reference to $\dot{V}O_2$ and respiratory exchange ratio, energy output was calculated; 3.5 ml/min/kg was considered to be 1 MET. Capillary samples for determination of lactate and catecholamine as well as the recording of RPE were carried out after 10 and 20 minutes of exercise during a 30 second break. Technical abnormalities and physical complaints were only recorded; no quantification was performed.

Statistical analysis

After normal distribution of data had been confirmed with the Kolmogoroff-Smirnov test, descriptive statistical analysis was performed; mean (SD) values were calculated. In the case of normally distributed data, a two factorial (intensity and time) analysis of variance was performed. The Scheffé test was used for post hoc comparisons. For ordinally scaled values (RPE), calculations were performed by non-parametric procedures (rank correlation according to Spearman). The significance level for the α error was set at $p<0.05$.

Table 1 Results from the incremental treadmill walking test

Variable	Max	IAT
Velocity (km/h)	8.3 (0.6)	6.9 (0.6) (83% V_{max})
Heart rate (beats/min)	166 (14)	131 (14)
Lactate (mmol/l)	6.1 (1.8)	2.0 (0.3)
$\dot{V}O_{2MAX}$ (ml/min/kg)	33.2 (5.1)	23.4 (4.8)
Energy cost (kJ/min)	46.7 (7.1)	32.9 (6.8)
MET	9.5 (1.5)	6.7 (1.4)

Values are maximal performance (Max) and individual anaerobic threshold (IAT) during walking and are expressed as mean (SD) (n = 16).

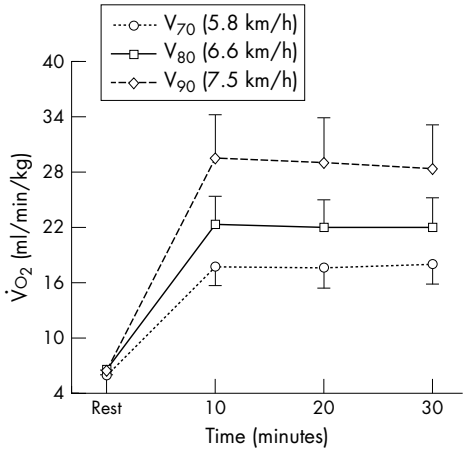

Figure 2 Oxygen uptake ($\dot{V}O_2$) during the 30 minute walking trials at 70%, 80%, and 90% of the maximal velocity obtained in the incremental treadmill walking test (V_{70}, V_{80}, and V_{90}). Values are mean (SD) (n = 16). All three values at each time point are significantly different from each other ($p<0.001$).

RESULTS

ITWT

During the ITWT, the subjects reached a mean (SD) V_{max} of 8.3 (0.6) km/h, and a mean (SD) $\dot{V}O_{2MAX}$ of 33.2 (5.1) ml/min/kg. Table 1 gives the ITWT results.

Walking trials

Oxygen uptake

The subjects reached a $\dot{V}O_2$ of 18.2 (2.3) ml/min/kg (55% $\dot{V}O_{2MAX}$) at V_{70}, 22.3 (3.1) ml/min/kg at V_{80} (67% $\dot{V}O_{2MAX}$), and 29.3 (5.0) ml/min/kg at V_{90} (88% $\dot{V}O_{2MAX}$). There was a significant effect of intensity on $\dot{V}O_2$. Figure 2 gives the results from post hoc testing. At V_{80}, V_{90}-, and V_{IAT} all subjects were above 60% $\dot{V}O_{2MAX}$.

HR

Mean HR reached 110 (9) beats/min during V_{70} (66% HR_{max}), 124 (9) beats/min during V_{80} (75% HR_{max}), and 152 (13) beats/min during V_{90} (93% HR_{max}) (fig 3). During V_{80} and V_{90} all subjects were above 65% HR_{max}. HR during the 80% endurance exercise was significantly ($p<0.05$) lower than HR at IAT (131 (14) beats/min, 79% HR_{max}). There was a significant effect of intensity on HR. Figure 3 shows different results from post hoc testing.

Lactate concentration

During the 30 minute walking tests, mean lactate concentration reached 1.1 (0.2), 1.8 (0.6), and 3.9 (2.0) mmol/l at V_{70}, V_{80}, and V_{90} respectively. There was a significant effect of intensity on lactate between V_{70} and V_{80} as well as between V_{80} and V_{90} (fig 4).

Energy consumption

The total energy consumption during the 30 minute walking tests was 744 (93) kJ (177 (22) kcal or 5.2 (0.7) MET) at V_{70}, 930 (129) kJ (221 (31) kcal or 6.3 (2.5) MET) at V_{80}, and 1224 (207) kJ (291 (49) kcal or 8.4 (1.4) MET) at V_{90}. There was a significant effect of intensity ($p<0.001$).

Catecholamine concentration

The catecholamine concentrations did not differ significantly between the three intensity levels. After 30 minutes of

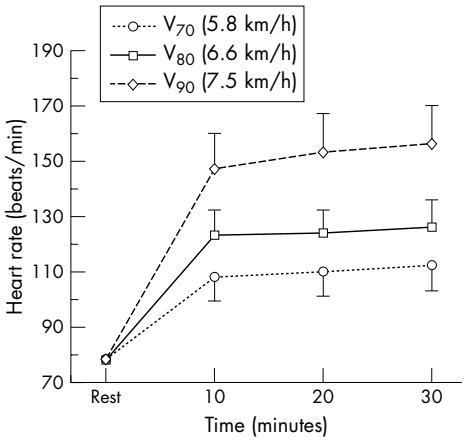

Figure 3 Heart rate during the 30 minute walking trials at 70%, 80%, and 90% of the maximal velocity obtained in the incremental treadmill walking test (V_{70}, V_{80}, and V_{90}). Values are mean (SD) (n = 16). All three values at each time point are significantly different from each other ($p<0.001$).

walking, the mean maximal free noradrenaline concentrations were 6.48 (2.17), 5.47 (1.34), and 6.26 (1.76) nmol/l at V_{70}, V_{80}, and V_{90} respectively. The corresponding adrenaline concentrations were 1.17 (0.28), 1.00 (0.27), and 1.10 (0.31) nmol/l.

RPE

A mean RPE of 10 (2) (''very easy'' to ''quite easy''), 12 (2) (''quite easy'' to ''a little difficult''), and 15 (2) (''difficult'') was recorded at V_{70}, V_{80}, and V_{90} respectively. There was a significant effect of intensity on RPE ($p<0.001$). An RPE of 19 (''very, very difficult'') was reported by one subject during V_{90}. At the end of the endurance test, 12 subjects felt that walking at V_{80} was more comfortable than at V_{70} or V_{90}.

Complaints

At V_{90}, 12 out of 16 subjects reported physical problems mainly in the lower legs. During V_{70} and V_{80}, no problems were reported by the subjects.

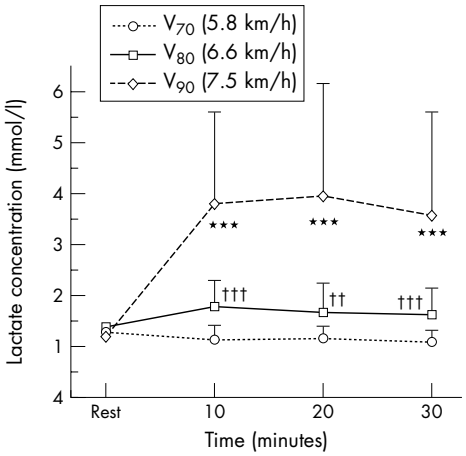

Figure 4 Lactate concentration during the 30 minute walking trials at 70%, 80%, and 90% of the maximal velocity obtained in the incremental treadmill walking test (V_{70}, V_{80}, and V_{90}). Values are mean (SD) (n = 16). ***Significantly different from V_{80} and V_{70} ($p<0.001$), ††,††† significantly different from V_{70} ($p<0.01$, $p<0.001$ respectively).

DISCUSSION

It has been shown that $\dot{V}O_2$ during V_{70} corresponds to the minimum intensity (55% $\dot{V}O_{2MAX}$) for training as recommended by ACSM, whereas V_{90} approaches the upper limit (88% $\dot{V}O_{2MAX}$).[8] Thus, low intensity walking at V_{70} may lead to health benefits when it is performed frequently and for long enough.[15] However, V_{80} (67% of $\dot{V}O_{2MAX}$) may be more appropriate for efficient endurance training. All subjects were above 60% $\dot{V}O_{2MAX}$ or 50% $\dot{V}O_{2R}$ during V_{80}. In contrast, V_{90} seems quite often to induce muscle pain in the lower legs even after only 30 minutes.

The mean maximal HR reached 220 minus age, indicating sufficient maximal effort on a treadmill.[16] If the mean HR response of the three walking endurance exercises is considered, at V_{70} the subjects are at the minimum HR, and at V_{80} and V_{90} they are within the recommended HR range. At V_{80} and V_{90}, all subjects are above the minimum HR described by ACSM.[8]

The mean lactate concentration during V_{70} was similar to resting concentrations, suggesting that the exercise intensity is low. During V_{90} the mean lactate concentration indicates intense physical performance. The mean lactate concentration during V_{80} was close to the IAT and within the range of extensive endurance training and[17] and thus compatible with appropriate recreational intensity.

According to Morris and Hardman,[3] in people with a body weight of about 70 kg, the energy consumption during walking on even ground at a velocity of 6.4–8.0 km/h corresponds to 25–36 kJ/min. In 40–56 year old men, Pollock *et al*[7] measured an energy consumption of 28.3–36.5 kJ/min for a velocity range of 6.8–7.6 km/h. The results of our study (5.8–7.5 km/h and 25–40 kJ/min) correspond well to these results.

The catecholamine concentrations did not differ significantly between intensities. Therefore this variable may not be suitable for defining efficient walking intensities. If the observed concentrations of noradrenaline and adrenaline are compared with those from earlier studies for cardiac patients during a strength endurance circuit and badminton training, they fall in the same range.[18 19]

Another variable that suggests that V_{80} is an adequate exercise intensity is the mean RPE (12 (2)). Dishman[20] recommends the same RPE for endurance training with appropriate intensity. Spelman *et al*[21] recommended an RPE of ''quite easy'' (Borg scale 11) for walking training with 50%

What is already known on this topic

- Data on appropriate training intensities for walking vary in the literature, and published test procedures only partly allow training recommendations to be derived
- Approaches using an incremental treadmill walking test (ITWT) as the basis for individual training recommendations are rare

What this study adds

- An ITWT is applicable for deriving individual intensity recommendations for walking training
- The most promising intensity is 80% of the maximal velocity reached during ITWT

of Vo_2MAX. Also, the 70% walking endurance performance was subjectively perceived as too low (''very easy'') and V_{90} was too intense and described as ''very difficult''.

Furthermore, orthopaedic problems occurred during the highest exercise intensity, mainly with pretibial muscles, as in earlier studies with recreational athletes.[22 23] Although symptoms in most cases disappeared quickly after exercise, straining beyond the pain limit should be avoided, as irreversible damage such as neurological disorders and muscle necroses has been described.[24 25]

In conclusion, an ITWT is appropriate for deriving individual intensity recommendations for walking training. The most promising intensity is 80% of the maximal velocity reached during ITWT.

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