TRAINING RESPONSES OF TWO AGE GROUPS DURING TREADMILL WALKING

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ABSTRACT

The purpose of the present study was to use a previously developed treadmill walking test to determine training-induced changes within and between two groups of untrained men during a six week training period. One group consisted of seven middle-aged (mean age, 41.3 yr), and the second group consisted of seven young adult (mean age, 19.9 yr), men. Heart rates following training were significantly lower at all work intensities for the middle-aged men ($p < 0.005$) whilst for the young adults only the 12.5% and 15% ($p < 0.025$) work levels were significantly lower. Blood lactic acid concentrations ($p < 0.005$), Respiratory Exchange Ratios ($p < 0.05$), Ventilatory Equivalents ($p < 0.005$) and mean Two Mile times ($p < 0.005$) were all significantly lower after training for the older age group but this was not so for the younger adult group. The oxygen cost of the walking test was lower for four of the workloads of the middle-aged, but only for the final workload ($p < 0.005$) for the young adults, after training. The performance test did not disadvantage the middle-aged subjects yet the results demonstrated that the test provided a common means of reflecting the training state of the two groups whether the level of activity took place on the treadmill or on the track.

Key words: Training, Metabolism, Ageing.

INTRODUCTION

The long association between VO_2 max and endurance capacity has tended to carry with it the assumption that VO_2 max is the single most important indicator of endurance fitness. This attitude often persists despite the fact that subjects are drawn from a wide range of age groups and reveal varying degrees of cardio-respiratory fitness. Recent research suggests that training-induced increases in endurance capacity are independent of VO_2 max (Bland and Williams, 1982) and this could place greater emphasis on submaximal forms of testing where there is less risk of overstrain, especially among untrained or older subjects. Even so, strenuous submaximal exercise could still induce a state of hypoxia so that a subject would be ill-advised to progress to more severe forms of testing until a more aerobic condition of fitness prevailed. Numerous studies have shown that, providing there are no differences in skill in performing a submaximal test, oxygen utilisation is similar in both the trained and untrained state (Clausen et al, 1969; Saltin and Karlsson, 1971; Varnauskas et al, 1966). Thus it is towards measures other than oxygen uptake that attention may need to be focussed in order to determine the fitness of the individual. The purpose of the present study was to determine whether a submaximal treadmill walking test, previously modified for a pilot study (Williams and Williams, 1983), was able to discriminate between the fitness levels of the two age groups over a training period of six weeks.

SUBJECTS

A group of twenty-two volunteer subjects participated in the study. Eight comprised the controls (mean age $\pm$ SD, 20 yr $\pm$ 1.1, range 18.9 to 22.3) of whom four were classed as 'untrained', four 'trained'. The fourteen subjects of the training study consisted of seven young (mean age 19.9 yr $\pm$ 0.42, range 19.2 to 20.5), and seven middle-aged (mean age 41.3 yr $\pm$ 5.8, range 35.1 to 50.3), men. The former were undergraduates from the University; the middle-aged group were from diverse backgrounds and professions including academic and non-academic occupations.

METHODS

The initial test for all subjects was a fifteen minute walk on a 72 inch (1.85 m) long treadmill, calibrated before the study. The test comprised five slopes at 5%, 10%, 12.5%, 15% and 17.5% each continuing for three minutes and maintained at a speed of 5.6 kmh^{-1} (3.5 mph) throughout. Prior to testing,

the height and weight of each subject, stripped to shorts, were taken. Vital capacity and forced expiratory volume in one second at BTPS were measured using a dry Spirometer (Vitalograph Ltd.). The subject was then rested for ten minutes during which time, resting blood pressure was measured using an electronic sphygmomanometer (Logos Medical Co. Ltd., Model LM-05) and resting heart rate using a pulsatile fingerstall (San-Ei Instrument Co. Ltd., Type PM-101). A five minute familiarisation period, walking on the treadmill, was followed by an obligatory one minute warm-up at the test speed with no elevation of the treadmill.

Heart rate was monitored continuously during the test and for five minutes of recovery. The test was terminated if a middle-aged subject exceeded his 'target heart-rate' as calculated from: $\text{HR max} = 210 - (\text{age} \times 0.65)$. The subject breathed through a low resistance Siebe Gorman 2.5 cm box valve connected, via a rubber mouthpiece and corrugated tubing, into a 120 litre capacity standard Douglas Bag. Expired air volumes and temperatures were measured by gasmeter after removing a two litre sample for gas analyses. Oxygen and carbon dioxide were analysed by paramagnetic and infra-red analysers respectively. Both analysers were calibrated with nitrogen, a reference gas and room air.

Blood samples were obtained from a finger-prick of the subject's pre-warmed hand before, and immediately after, the test. Haematocrits were determined from blood collected in heparinised tubes, centrifuged and read from the Hawksley Micro Scale. Haemoglobin concentrations were determined by the standard cyanomethoglobin method, whilst deproteinised blood samples, frozen in aliquots at -20°C were later analysed for lactic acid using a modified fluorimeter method developed by Olsen (1971).

The Thirty Minute Endurance Test

Those participating in the training programme were required to include a thirty minute treadmill walk and a field test as part of their schedule at the beginning and conclusion of training. The walk was at a constant speed of 5.6 kmh^{-1} and at an exercise intensity equivalent to 80% of the peak VO_2 determined at the completion of the fifteen minute uphill walking test. A regression equation was calculated between VO_2 and work intensity for each subject and, by interpolation, the gradient for the thirty minute test was determined.

Heart rates were monitored at rest, throughout the test and during ten minutes of recovery. Expired air samples were collected for analysis every ten minutes during the test; blood pressure was taken at rest and between nine and ten minutes post-exercise. Blood samples for lactic acid analysis were obtained pre- and four minutes post-exercise. Subjective responses were followed using Borg's Rate of Perceived Exertion Scale.

The Field Test

A two mile (3203 m) performance test was obligatory for the training groups. Two runs were completed: one during the first two days, and the other on the final day, of training. This provided a commonly accepted measure of fitness in a manner to which each subject could readily relate.

Subjects were required to train over a six week period, three times a week for at least twenty minutes on each occasion. This comprised a minimum total of at least eighteen training sessions, four of which were closely monitored. Information was provided for each subject, recommending the type of training to be followed and guidelines as to the use of the Cooper twelve minute test. A detailed training diary was also completed by each subject.

RESULTS

The heights and weights of the groups were: middle-aged, young adult and control groups, 174.4 (± 7.5) cm, range 165.3 to 182.3 and 73.8 (± 13.5) kg, range 59.1 to 92.9; 186.9 (± 8.4) cm, range 173.7 to 194.4 and 75.7 (± 10.2) kg, range 65.8 to 95.5; 176.2 (± 5.6) cm, range 168.2 to 184.1 and 68.8 (± 8.8) kg, range 54.2 to 80.2 respectively with no significant changes in weight over the training period.

Blood pressure showed little change for the middle-aged group but the systolic pressure was significantly lower ($p < 0.025$) for the young adults after training. The diastolic pressure of the controls was significantly higher ($p < 0.05$) after the six week period. During the fifteen minute walking test, heart rates were significantly lower ($p < 0.005$) at the 10%, 15% and 17.5% gradients for the middle-aged subjects following training and at all other levels ($p < 0.01$ and $p < 0.05$) of exercise and up to five minutes of recovery (Fig. 1). The heart rates of the young adults were lower ($p < 0.025$) at the 12.5% and 15% gradients and during the first, second, fourth and fifth minutes of recovery ($p < 0.05$; Fig. 2) but otherwise were not significantly lower.

Neither packed cell volume (haematocrit) nor haemoglobin concentrations changed significantly over the training period in either training groups and the walking test did not produce any detectable change in haemoconcentra-

Fig. 1: The changes in heart rates of the middle-aged men during the uphill treadmill walking test before and after six weeks of training.

Fig. 2: The changes in heart rates of the young adults during the uphill treadmill walking test before and after six weeks of training.

tion. However, there was a significant increase ($p < 0.05$) in the haemoglobin concentration of the controls. Blood lactic acid concentrations of the older group were significantly lower after training ($p < 0.005$) compared with the pre-training values following the fifteen minute walk; the concentrations of the young adults also fell, but not significantly (Table I). In contrast, the post-six week lactate concentration levels of the controls were higher than when measured at the beginning of the study, but not significantly. The final thirty minute walk at the conclusion of training revealed a fall in lactic acid concentration for both training groups, significantly so for the young adults ($p < 0.05$) in comparison with measures early in training.

TABLE I
Cardiac and haematological responses pre- and post-six weeks of training (Mean $\pm$ SD)

Variable	n	Middle-aged 7	Young Adults 7	Controls 7
Haemoglobin (g.dl ⁻¹)	Pre	14.8 $\pm$ 0.4	13.9 $\pm$ 1.2	13.6 $\pm$ 0.9
	Post	14.6 $\pm$ 0.7	13.9 $\pm$ 0.8	13.9 $\pm$ 1.0*
Haematocrit (%)	Pre	42.7 $\pm$ 2.6	41.7 $\pm$ 2.6	41.1 $\pm$ 2.6
	Post	42.2 $\pm$ 3.1	42.5 $\pm$ 2.3	41.6 $\pm$ 2.3
Lactate conc. (mM)	Pre	7.8 $\pm$ 2.9	2.5 $\pm$ 1.2	3.8 $\pm$ 1.8
	Post	5.6 $\pm$ 2.1***	2.2 $\pm$ 1.4	4.3 $\pm$ 2.4
Blood Pressure (mmHg)	Pre	122 : 90	129 : 70	131 : 65
	Post	128 : 86	**124 : 74	135 : 79*
Heart Rates† (beats.min ⁻¹)	Pre	175.0 $\pm$ 10.0	138.0 $\pm$ 5.0	144.0 $\pm$ 8.0
	Post	154.0 $\pm$ 8.0***	137.0 $\pm$ 6.0	145.0 $\pm$ 12.0

* $p < 0.05$ ** $p < 0.025$ *** $p < 0.005$ †Measured at the 17.5% gradient

There were no significant differences in ventilatory variables (Vital Capacity and FEV₁) pre- and post-training for any of the groups (Table II). The oxygen cost of the fifteen minute walk was significantly lower after training ($p < 0.05$) at all gradients except at the 15% gradient for the middle-aged group (Fig. 3) whilst for the young adults it was only lower at the final, 17.5% gradient ($p < 0.005$; Fig. 4). It was noticeable that the lower oxygen values of the middle-aged group were obtained from lower pulmonary ventilations ($p < 0.05$) at all gradients except at the 5% gradient whereas only the samples at the 15% gradient from the young adults ($p < 0.05$) showed this difference. In contrast, the pulmonary ventilation of the control group increased significantly ($p < 0.05$) over the training period with no change in the oxygen uptake. The R values of the middle-aged group were significantly reduced ($p < 0.05$) following the fifteen minute retest and closely mimicked those of the young adults and controls (Table II). There were no changes in the

TABLE II
Ventilatory measures pre- and post-six weeks of training
(Mean $\pm$ SD)

Variable	n	Middle-aged 7	Young Adults 7	Controls 7
Vital Capacity (Litres)	Pre	5.00 $\pm$ 1.00	6.40 $\pm$ 1.00	5.50 $\pm$ 0.90
	Post	5.30 $\pm$ 1.10	6.30 $\pm$ 1.10	5.50 $\pm$ 1.00
FEV ₁ (Litres)	Pre	4.40 $\pm$ 0.90	5.50 $\pm$ 0.90	4.80 $\pm$ 0.60
	Post	4.20 $\pm$ 0.90	5.50 $\pm$ 1.00	4.80 $\pm$ 0.70
VO ₂ [†] (ml.kg.min ⁻¹)	Pre	38.40 $\pm$ 1.80	39.20 $\pm$ 3.90	39.60 $\pm$ 3.10
	Post	37.20 $\pm$ 1.70*	35.80 $\pm$ 2.60***	39.40 $\pm$ 3.90
VE [†] (L.min ⁻¹)	Pre	80.80 $\pm$ 22.80	59.60 $\pm$ 11.30	55.90 $\pm$ 11.70
	Post	71.70 $\pm$ 19.50***	54.60 $\pm$ 8.50	59.80 $\pm$ 8.50*
R [†]	Pre	1.18 $\pm$ 0.10	1.04 $\pm$ 0.10	1.00 $\pm$ 0.13
	Post	1.10 $\pm$ 0.10*	1.07 $\pm$ 0.14	1.09 $\pm$ 0.15
(Resp. Exch. Ratio)				

*p < 0.05

***p < 0.005

†Measured at the 17.5% gradient

Middle-aged

Fig. 3: The oxygen consumption of the middle-aged men during the uphill treadmill walking test before and after six weeks of training.

Young Adults

Fig. 4: The oxygen consumption of the young adults during the uphill treadmill walking test before and after six weeks of training.

oxygen demands of the two groups in completing the thirty minute walk following training except in the second sample, taken after twenty minutes, for the young adults when there was a significant fall ($p < 0.05$). However, the middle-aged group did reveal a significant reduction ($p < 0.01$) in their pulmonary ventilations during this test and this was not shown by the younger subjects.

There were no significant differences in estimation of Rate of Perceived Exertion (RPE) pre- and post-training by the two groups in completing the fifteen minute test. When RPE was related to maximum heart rates, there were modest correlations of 0.68 and 0.46 before and after training respectively, by the middle-aged subjects, poor correlations of 0.27 and 0.12 by the young adults whereas the controls revealed modest to high negative correlations of -0.57 and -0.85 pre- and post-six weeks.

All subjects of the middle-aged group improved their two mile run times during the post-training test. The average time of the group was lowered from 15.95 min to 14.34 min, a significant improvement of 1.61 min ($p < 0.005$). Two of the young adults failed to improve their times though the group as a whole improved by 0.31 min from 13.76 min to 13.45 min but this was not statistically significant.

A Two-way Analysis of Variance with repeated measures on age and exercise intensity was calculated between the middle-aged and young adult groups for the fifteen minute test. Oxygen uptake ($p < 0.01$), heart rates ($p < 0.01$), Respiratory Exchange Ratios ($p < 0.01$) and Ventilatory Equivalents ($p < 0.05$) were found to be significantly different when comparing exercise intensity as a result of the six week training period. When comparing oxygen uptake, R values, Ventilatory Equivalents and post-fifteen minute treadmill walking lactate concentrations in relationship to age differences there were no significant changes; however, there were significant differences in heart rates between the pre-training and post-training values ($p < 0.01$).

DISCUSSION

The prototype for the fifteen minute treadmill walking test was devised by Bruce (1972) and subsequently modified by Williams and Williams (1983). The present test was modified further in that it incorporated three-minute exercise intensity periods in order to attempt to establish, more closely, a condition of aerobic 'steady state'. Thus the concept of the test moved away from 'maximum work capacity' where the test, or any part of it, is short in duration and intensely demanding in energy expenditure. None of the groups found difficulty in performing the test, though some individuals discovered that it was more exacting than they had imagined, particularly during its later stages.

The main finding of this study was that the test, acceptable to diverse age groups, was able to reveal metabolic differences by means of the levels of work intensity selected. It clearly demonstrated a 'training effect' for an untrained middle-aged group. The test also reflected the significant changes that occurred to a group of young adults both on the treadmill and on the track during a six week training period of limited intensity. The Two-Way Analysis of Variance supported the main finding in revealing that age differences were not significant except in cardiac efficiency. This would suggest that if, as a subject ages, he does not perform sufficient exercise to induce a training effect, then the condition of the cardiovascular system would not be maintained at an efficient level.

Such cardiovascular responses to the period of physical conditioning are reflected in the inter-relationships between blood lactates, oxygen uptake and heart rates. After

training, the lactic acid concentrations of the middle-aged group were significantly lower but still remained twice as high as those of the young adults and did not fall below those of the controls (Table I). These high lactate concentrations, even after training, together with the higher R values (Table II) indicate continuing dependence on glycolysis and an inability to complete absolute levels of submaximal exercise intensity other than by obtaining a contribution to aerobic metabolism from anaerobic mechanisms of energy production. Theoretically, the older person may be required to tolerate higher lactic acid concentrations and lower alkali reserves for a longer period of time by virtue of his age alone when performing submaximal work. Increased age also involves a decrease in cardiovascular compliance as exhibited by the increased systolic pressures of the middle-aged subjects. Alternatively, the period of conditioning may not have been long enough to raise the anaerobic threshold to the higher percentage of $\dot{V}O_2$ max (Davis et al, 1979) achieved by the more highly trained young adults as revealed by their low blood lactates. Thus, whereas the middle-aged group may have been working at as high a level as 75% $\dot{V}O_2$ max during the final level of exercise intensity of the walking test, the young adults would be required to tax no more than 60% $\dot{V}O_2$ max in completing the walk (Gollnick and Hermansen, 1973).

Consequently, although the oxygen uptake measures are consistent with the findings of both the pilot study and previous work, they mask the contrasting levels of stress in terms of percentage $\dot{V}O_2$ max by the two trained groups. Certainly the middle-aged group's post-training oxygen uptake values which were consistently lower at all but the 15% workload (Fig. 3), suggest improved mechanical efficiency. However, one of the few indications of the training effect by the young adults is the significantly lower oxygen cost of the final workload (Fig. 4) achieved at a reduced energy expenditure of $3.2 \text{ kJ} \cdot \text{min}^{-1}$ (72.4 Watts) (Weir, 1949) below that of the older group. These differences were also apparent when comparing the Ventilatory Equivalents of 26.5 and 20.3 for the middle-aged and young adult groups respectively.

The increased oxidative capacity of the skeletal muscles following physical conditioning is matched by the significantly lower heart rates, especially for the middle-aged men (Figs. 1 and 2). It is debatable whether these changes in heart rate are of central or peripheral origin. Blood flow to the viscera is known to increase during submaximal exercise after conditioning whilst that through skeletal muscles remains the same or is decreased slightly (Varnauskas et al, 1970). The virtually unchanged heart rates and blood lactates of the young adults, post-training, would appear to indicate that benefit from peripheral inhibitory mechanisms (Ekblom et al, 1973) is at an optimum in terms of improved oxygen extracting capacity by the tissues from similar, or lowered, blood flow (Trueman and Schroeder, 1968). The lower heart rates of the middle-aged subjects may be more tentatively attributed to the improved stroke volume as a result of the conditioning they have undergone. More pronounced peripheral influences on cardiac output could be anticipated only with a more prolonged conditioning regimen which would increase the aerobic capacity of the skeletal muscles. This, 'a priori', would favour a more

aerobic response to the walking test with lowered blood lactates.

Rate of Perceived Exertion, when correlated with heart rates, generally showed measures below those reported in the literature (Skinner et al, 1970). Nevertheless, middle-aged subjects found the Borg Scale a valuable aid both during training and testing and especially in gauging distribution of effort. Improved fitness seems to bring with it a diminishing regard for any psychological manifestation of physical stress which inadvertently becomes less acute.

In summary, the study has shown that a young, comparatively fit, adult group revealed no change in performance on the track following six weeks of training and this was mimicked by no change in physiological measures on a treadmill walking test. An unfit middle-aged group, on the other hand, significantly improved its track performance and these changes have been clearly revealed by measurements taken during the same treadmill test. The test has thus been sufficiently sensitive in discriminating between the training-induced differences in fitness of two age groups both on the treadmill and as revealed by performances on the track.

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