ORIGINAL ARTICLE

Training effects of short bouts of stair climbing on cardiorespiratory fitness, blood lipids, and homocysteine in sedentary young women

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Objectives: To study the training effects of eight weeks of stair climbing on $\dot{V}O_2$MAX, blood lipids, and homocysteine in sedentary, but otherwise healthy young women.

Methods: Fifteen women (mean (SD) age 18.8 (0.7) years) were randomly assigned to control (n = 7) or stair climbing (n = 8) groups. Stair climbing was progressively increased from one ascent a day in week 1 to five ascents a day in weeks 7 and 8. Training took place five days a week on a public access staircase (199 steps), at a stepping rate of 90 steps a minute. Each ascent took about two minutes to complete. Subjects agreed not to change their diet or lifestyle over the experimental period.

Results: Relative to controls, the stair climbing group displayed a 17.1% increase in $\dot{V}O_2$MAX and a 7.7% reduction in low density lipoprotein cholesterol ($p<0.05$) over the training period. No change occurred in total cholesterol, high density lipoprotein cholesterol, triglycerides, or homocysteine.

Conclusions: The study confirms that accumulating short bouts of stair climbing activity throughout the day can favourably alter important cardiovascular risk factors in previously sedentary young women. Such exercise may be easily incorporated into the working day and therefore should be promoted by public health guidelines.

Physical activity is now well established as a key component in the maintenance of good health and disease prevention.[1] Despite this, less than 20% of adults in most developed countries are sufficiently active to derive any discernible health and fitness benefits.[2] Furthermore, it has been hypothesised that increasing physical activity in previously sedentary people may prove the most effective strategy for prevention of cardiovascular disease (CVD) on a population basis.[3]

Current physical activity guidelines recommend that every adult should engage in 30 minutes or more of moderate intensity physical activity on most, preferably all, days of the week.[4] One strategy advocated to meet this activity goal is to accumulate exercise in short bouts throughout the day. The efficacy of this approach has been shown experimentally using 10 minute bouts of activity.[5] However, to date only one stair climbing study has shown that accumulating very short bouts of exercise lasting about two minutes can also confer health benefits.[6] Some limitations of this study were that the cardiorespiratory adaptations noted were not determined using maximal oxygen consumption ($\dot{V}O_2$MAX), and the other CVD risk factors measured were restricted to total cholesterol (TC) and high density lipoprotein cholesterol (HDL-C).

Therefore the purpose of this study was to: (*a*) determine if the previously reported cardiorespiratory adaptations[6] to accumulated bouts of stair climbing could be replicated using direct measurement of $\dot{V}O_2$MAX; (*b*) investigate the effects of accumulated bouts of stair climbing on a wider spectrum of CVD risk factors including, TC, HDL-C, low density lipoprotein cholesterol (LDL-C), triglycerides, and homocysteine.

METHODS

Design

This was an eight week intervention study involving previously sedentary young women randomly assigned to stair climbing or control groups after baseline testing. The protocol was approved by the research ethics committee of the Queens University, Belfast, and each participant gave written consent after a full explanation of the procedures and risks involved. Measurements were made at baseline and again after eight weeks of training. All subjects agreed not to change their diet or lifestyle over the experimental period.

Subjects

Volunteers were recruited from the local university undergraduate population through the administration of a self report health and lifestyle questionnaire to 103 female students. Exclusion criteria for volunteers included a history of cardiovascular disease, cigarette smoking, hypertension (systolic/diastolic blood pressure >140/90 mm Hg), diabetes, obesity (body mass index $\geq$30 kg/m^2), musculoskeletal injury, or the taking of any pharmacotherapeutic drug. Subjects were also required to be sedentary—that is, participation in exercise or sport on one or no occasions each week. Eighteen subjects volunteered to take part in the study, of whom 15 satisfactorily completed the study. Of the three subjects who withdrew from the study, one cited insufficient time, one completed the intervention but failed to complete the testing afterwards, and one developed a medical condition that contraindicated exercise.

Cardiorespiratory fitness

$\dot{V}O_2$MAX was determined using an incremental test to volitional fatigue on an electronically braked cycle ergometer (Cardiotest 100; Seca, Hamburg, Germany). The test protocol consisted of an initial workload of 40 W, which was increased by 40 W every three minutes, using a pedalling frequency of 60–70 rpm. Heart rate was monitored by a short

Abbreviations: CVD, cardiovascular disease; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; TC, total cholesterol; $\dot{V}O_2$MAX, maximal oxygen consumption wave telemetry system (Vantage NV; Polar Electro, Kempele, Finland). Expired respiratory gases were measured continuously and averaged over 30 second intervals with a Quinton Metabolic Cart (QMC; Quinton, Seattle, Washington, USA).

The oxygen uptake test was considered maximal if at least two of the following criteria were met[7]: heart rate at test termination >85% of age predicted maximum (220 − age), a respiratory exchange ratio at test termination >1.00, or a plateau for VO_2 (defined as an increase $\leq$2 ml/kg/min despite further increases in workload).

Anthropometry

Height and body mass were determined using standard methods. Body mass index was calculated by dividing weight (kg) by height squared (m^2).[8]

Blood lipids and homocysteine

Venous blood samples (10 ml) were obtained from an antecubital vein, after a 12 hour overnight fast, with subjects in a seated position and rested for five minutes. Post-intervention samples were obtained 60 hours after the last stair climb to control for any possible transient effects of physical activity on blood lipid concentrations.[9] On the day of their pre-intervention blood samples, all subjects were asked to complete a form indicating the stage of their menstrual cycle. Post-intervention blood samples were scheduled for the same stage of each subject's menstrual cycle, to minimise the potential effects of endogenous hormones on blood lipid concentrations.

Serum TC, triglycerides, and HDL-C were analysed using a Vitros 950 IRC automated analyser (Johnson and Johnson, New Brunswick, New Jersey, USA). The concentration of LDL-C was calculated using the Friedwald formula.[10] Total homocysteine was determined by high performance liquid chromatography by previously described methods.[11] All samples were assayed in the same batch, within a laboratory subject to external quality control (United Kingdom National Quality Assurance Scheme).

Exercise prescription

Subjects allocated to the exercise group embarked on an eight week progressive stair climbing programme. The programme began with two bouts of stair climbing five days a week in weeks 1 and 2, increasing by one climb a day every two weeks. By the last two weeks (7 and 8) of the study, all subjects were completing five bouts of stair climbing five days a week. Subjects climbed in a public access staircase, which consisted of 199 steps with a total vertical displacement of 32.8 m. The prescribed exercise intensity involved climbing the eight flights of stairs at a comfortable but brisk rate (90 steps a minute), determined previously in a stair climbing intervention using these facilities,[6] and to descend thereafter at their own pace.

Training logs were kept by all subjects to document the completion of each stair climb. Each bout of stair climbing was integrated into the working day at the convenience of the subject, with a minimum of one hour between climbs. To encourage compliance with the programme and the prescribed intensity of exercise, all stair climbers had supervised sessions once a week. This was supplemented by regular telephone calls, and all subjects were also provided with contact numbers to call if they needed help or information.

Statistical analysis

Changes over time were adopted as a summary measure of the response over time for each subject.[12 13] Mean changes were compared using an unpaired *t* test to identify differences in response between groups. The 0.05 level was used as the criterion for statistical significance. The results are given as mean (SD).

RESULTS

Baseline characteristics of the subjects

Table 1 presents the subjects' characteristics at baseline. There were no significant differences between groups for any variable.

Compliance with training

Compliance in the stair climbing group was good, with a mean 114 (9) (range 97–123) climbs completed out of a possible 130 over the experimental period.

Training effects of stair climbing

Table 2 presents the changes in the dependent variables of interest for the groups over the eight week intervention period. There were no significant changes in body mass index, TC, HDL-C, TC/HDL-C ratio, triglycerides, or homocysteine. Relative to controls, the stair climbing group showed a significant increase in VO_2MAX and a reduction in LDL-C ($p<0.05$).

DISCUSSION

These findings show that an eight week stair climbing programme characterised by multiple short bouts of vigorous activity can result in positive changes in important CVD risk factors, namely VO_2MAX and LDL-C, in a previously sedentary group of young women.

This stair climbing study is the first to show an improvement in cardiorespiratory fitness using direct measurement

Table 1 Characteristics of subjects at baseline

	Control (n = 7)	Stair climbers (n = 8)
Age (years)	18.7 (0.8)	18.9 (0.6)
BMI (kg/m^2)	21.9 (2.0)	20.9 (1.5)
VO_2MAX (ml/kg/min)	30.0 (4.9)	26.3 (5.1)
TC (mmol/l)	4.32 (0.34)	4.03 (0.45)
HDL-C (mmol/l)	1.55 (0.35)	1.42 (0.25)
LDL-C (mmol/l)	2.19 (0.39)	2.15 (0.57)
TC/HDL-C ratio	2.91 (0.74)	2.93 (0.69)
Triglycerides (mmol/l)	1.28 (0.46)	1.02 (0.31)
Homocysteine (μmol/l)	7.17 (2.50)	7.04 (1.71)

Values are mean (SD). No significant differences between groups ($p>0.05$).
BMI, Body mass index; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; TC, total cholesterol; VO_2MAX, maximal oxygen consumption.

Table 2 Change over time for each of the dependent variables

	Control (n = 7)	Stair climbers (n = 8)
BMI (kg/m^2)	0.0 (0.5)	+0.2 (0.5)
VO_2MAX (ml/kg/min)	+1.0 (2.1)	+4.5 (3.7)*
TC (mmol/l)	+0.21 (0.25)	−0.05 (0.41)
HDL-C (mmol/l)	+0.09 (0.27)	−0.05 (0.11)
LDL-C (mmol/l)	+0.17 (0.32)	−0.17 (0.27)*
TC/HDL-C ratio	−0.11 (0.51)	−0.12 (0.15)
Triglycerides (mmol/l)	−0.11 (0.26)	−0.15 (0.34)
Homocysteine (μmol/l)	+0.04 (0.93)	−0.35 (0.66)

Values are mean (SD).
*Change from baseline significantly different from change in controls ($p<0.05$).
BMI, Body mass index; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; TC, total cholesterol; VO_2MAX, maximal oxygen consumption.

of $\dot{V}O_{2MAX}$, regarded as the gold standard in fitness assessment.[14] Previous stair climbing investigations[15–17] have been limited to the use of submaximal testing to predict $\dot{V}O_{2MAX}$, which have reported errors of 10–15%.[18] The substantial 17.1% improvement in $\dot{V}O_{2MAX}$ reported in the present study provides evidence that just over 11 minutes a day of stair climbing is sufficient to elicit cardiovascular adaptations. This improvement was similar to the change observed by Ilmarinen *et al*[16] and is within the range (5–25%)[15–17] reported in the literature for stair climbing exercise.

Although genetic predisposition may account for about 40% of the variation in $\dot{V}O_{2MAX}$,[19] physical activity is the key determinant of the remaining 60%.[20] Low levels of cardiorespiratory fitness have been found to be as strong a predictor of mortality as the conventional risk factors, such as cigarette smoking, and are a stronger predictor than hypercholesterolaemia and hypertension.[21] It has also been observed that even small improvements in cardiorespiratory fitness can result in reduced risk of all cause mortality.[22 23] Improvement in cardiorespiratory fitness of the magnitude shown in this study should reduce risk of mortality by about 20%,[22] and therefore may have considerable implications for public health policy.

Beneficial changes in $\dot{V}O_{2MAX}$ have repeatedly been reported for exercise training programmes, typically of the range 5–30%.[24] What is striking about the present study, however, is that the training time invested was considerably less than other programmes. The 11 minutes a day of stair climbing performed in the final weeks of the eight week programme resulted in similar improvements to $\dot{V}O_{2MAX}$ as walking for 36 minutes a day over 24 weeks.[25] It appears therefore that, when the intensity of effort relative to a person's $\dot{V}O_{2MAX}$ is high, the duration of exercise may be considerably reduced for comparable health and fitness benefits. Previously it has been shown that, when the volume of exercise is held constant, intensity has a profound dose-response impact on the magnitude of the improvement in $\dot{V}O_{2MAX}$.[25] It seems that the effectiveness of the present programme was primarily due to the relatively vigorous nature of stair climbing,[6] despite the low overall volume of exercise. Therefore, in today's society when a lack of time is the most often cited reason for not being physically active,[4] the promotion of stair climbing should receive greater emphasis in public health recommendations when not contraindicated on health grounds.

There is broad agreement that physical activity is independently associated with a reduced risk of coronary heart disease[26] and that at least part of this reduction may be due to favourable changes in circulating lipids induced by regular physical exercise.[27] Of the various lipoproteins, LDL-C is most strongly associated with the risk for CVD and accounts for most of the risk resulting from raised TC concentrations.[28] Although the study was not powered to detect changes in lipid profiles, we found a reduction in LDL-C in the exercise group compared with the control subjects. In part, this was due to a non-significant rise in LDL-C in the control subjects. The reduction in LDL-C with no concomitant increase in HDL-C is similar to previous observations using walking exercise.[29 30] The effect of exercise training on LDL-C has usually been rather small, typically in the range 5–10%, and highly variable, although a number of suitably designed and executed training studies have on a regular basis reported lower plasma LDL-C concentrations after training.[31] Dietary composition is known to influence lipoprotein concentrations and is an obvious potentially confounding factor in this study. Although dietary analysis was not completed, each subject was requested not to change dietary habits during the study. It has been previously reported that exercise training does not result in changes in nutrient intake or ratios of protein, carbohydrates, and fats.[32] Thus it seems unlikely that dietary factors influenced the changes in lipoprotein concentrations reported.

What is already known on this topic

Current physical activity guidelines recommend that every adult should engage in 30 minutes or more of moderate intensity physical activity on most, preferably all, days of the week.

What this study adds

Evidence is provided that stair climbing is an efficient, discrete, and well tolerated way of satisfying the recommendations on physical activity.

The lack of change in HDL-C in this study is contrary to findings from previous similar work[6] and other exercise training studies.[27] However, approximately half of all exercise training studies also report no change or even a decrease in HDL-C.[33] Reasons for the wide variation in reported responses include the timing of post-intervention blood samples and initial concentrations of HDL-C. Most published exercise training studies have not controlled for time of blood sampling. If sampling occurs within 48 hours of the last training session, findings attributed to training may be confounded by transient changes in blood lipids induced by the "last bout" of exercise.[9] In the present study, particular care was taken to reduce this possibility. Furthermore, the high initial concentrations of HDL-C in the stair climbing group (1.42 (0.25) mmol/l), which approaches the level regarded as a negative risk factor for CVD (1.55 mmol/l),[34] and the relatively small size of the study group may have reduced the potential for any improvement in this study.[31]

A number of intervention trials have investigated the effects of exercise on homocysteine, and in general results are inconsistent. However, acute exercise has been reported in several studies to produce modest increases in homocysteine, with longer term exercise programmes having no effect or beneficial effects. In addition, improvements in homocysteine have most commonly been reported in subjects with raised baseline homocysteine or poor fitness.

Several studies[35–37] have reported increases in homocysteine in the few hours after acute exercise. It is possible that this is in part due to haemoconcentration. However, Hermann *et al*[37] also described more persistent modest increases in homocysteine after three weeks of strenuous swimming. In contrast with these studies, Wright *et al*[38] found no effect of acute exercise.

Decreased homocysteine after an exercise programme leading to weight loss in overweight women with polycystic ovary syndrome was described by Randeva *et al*.[39] In addition, a cardiac rehabilitation programme produced a 12% decrease in homocysteine only in subjects with raised baseline concentrations, although it was unclear to what extent this might have represented regression to the mean.[40] It is possible that exercise intensity may influence homocysteine responses, although very little work has addressed this; Vincent *et al*[41] suggested in subgroup analysis that a six month, high intensity, resistance training programme produced a small reduction in homocysteine, with a less intense programme having no effect. The results of our study show no effect of stair climbing on homocysteine. However, post hoc calculations suggest that the study only had sufficient power to detect a 1 μmol/l difference in homocysteine change between the intervention and control groups, so it is important not to overinterpret these negative findings.

In conclusion, the results of this randomised, controlled exercise training trial show that short bouts of stair climbing five days a week provide sufficient stimulus to positively influence important CVD risk factors, namely VO_2MAX and LDL-C concentrations, in previously sedentary young women. Stair climbing appears to be an efficient, discrete, and well tolerated form of exercise. Furthermore, it requires no specialised facilities or equipment, and is accessible to large sections of industrialised society. Its promotion could have important implications for public health.

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