©Journal of Sports Science and Medicine (2007) **6**, 448-454
http://www.jssm.org

Research article

Evaluating the effects of a low volume stairclimbing programme on measures of health-related fitness in sedentary office workers

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Abstract
Despite its obvious advantages, few studies have examined health outcomes of regular stariclimbing. In this study, we investigated the training effects of eight weeks of stairclimbing on recognised measures of health-related fitness in an occupational setting. Forty-five public sector employees (22 male, 23 female) aged 42.3 ± 9.0 years were randomly assigned to control (n = 16) or stairclimbing (n = 29) groups. Stairclimbing training began with 1 bout $5d\cdot wk^{-1}$ in week 1, increasing by one climb per day every two weeks until week 5, where a maintenance level of 3 climbs per day was reached. Participants climbed on staircases located within an 8 storey office block, consisting of 145 steps. The prescribed exercise intensity involved climbing the 8 flights of stairs at a rate of 75 $steps\cdot min^{-1}$. All participants agreed not to change their diet or lifestyle over the experimental period. Relative to controls, the stairclimbing group showed a significant increase of 9.4% in predicted VO_{2max} ($p < 0.05$). No significant changes in blood pressure, blood lipid concentrations or body composition were noted. These findings provide evidence that stairclimbing can enhance an important component of health-related fitness, namely cardiovascular fitness. Given that such improvement resulted from less than 30 minutes per week of moderate exercise, stairclimbing in the workplace should be promoted as a health-enhancing physical activity.

Key words: Exercise therapy, physical fitness, dyslipidemias, occupational health.

Introduction

A physically active lifestyle is well established as a central component in the maintenance of good health and disease prevention (Shephard, 1999). However, the majority of adults in our society appear reluctant to undertake even the minimum exercise recommendation to achieve discernible health benefits (Pate et al., 1995). Moreover, the prevalence of sedentary behaviour is greater than that for cigarette smoking, hypercholesterolemia, or hypertension (U.S. Department of Health and Human Services, 1996). Consequently, it has been postulated that the overall impact of stimulating our society to engage in a more active lifestyle could effectively lower coronary heart disease (CHD) rates, to a greater extent than by altering any other single risk factor (Caspersen and Heath, 1993).

The increased mechanization and automation of work procedures means the longest sedentary phase in waking hours, for many people, occurs during the working day (Ilmarinen et al., 1979). The workplace has therefore been identified as a critical setting for the delivery of interventions designed to reduce chronic disease among adult populations (Oldenburg and Harris, 1996). Ideally, the programme must not interfere with work, take only a minimal amount of time, incur no financial costs, involve no special equipment and be effective in altering health-related fitness (Booth et al., 1997; Bouchard and Shephard, 1994; Ilmarinen et al., 1979; Zunft et al., 1999). One possible solution is the inclusion of stairwalking into the daily schedule, particularly in an urban working environment that offers few alternative forms of exercise (Winett and Carpinelli, 2000). Stairclimbing is a familiar mode of activity that has been shown to independently predict longevity in populations (Lee and Paffenbarger, 2000; Paffenbarger et al., 1994).

Despite the apparent practicality of stairwalking in an urban occupational setting, only a paucity of literature has investigated the potential health benefits. The first report evaluating the feasibility and efficacy of stairclimbing dates back to Fardy and Ilmarinen (1975). This investigation showed that, in a subgroup of men climbing about 25 $floors\cdot day^{-1}$ or 125 $floors\cdot week^{-1}$, maximal oxygen consumption (VO_{2max}) increased by about 10% over a 12-week period. Four subsequent investigations with sedentary men and women have been carried out; these studies have reported improvements (≈5-25%) in VO_{2max} (Fardy and Ilmarinen, 1975; Ilmarinen et al., 1979; Ilmarinen et al., 1978, Boreham et al., 2005) and other indices of cardiorespiratory fitness and blood lipid concentrations (Boreham et al., 2000; Boreham et al., 2005).

To date, the effects of smoking cessation and changes in dietary habits on risk factors for CHD have been the focus of most worksite health promotion interventions, with only a small number of randomised-controlled trials targeting physical activity (Emmons et al., 1999). Therefore, the purpose of the present study was to investigate the effects of accumulated bouts of stairwalking on cardiorespiratory fitness, body composition and blood lipids in sedentary office workers.

Methods

Study design

This was an 8-week intervention study involving

Received: 10 May 2007 / Accepted: 18 July 2007 / Published (online): 01 December 2007

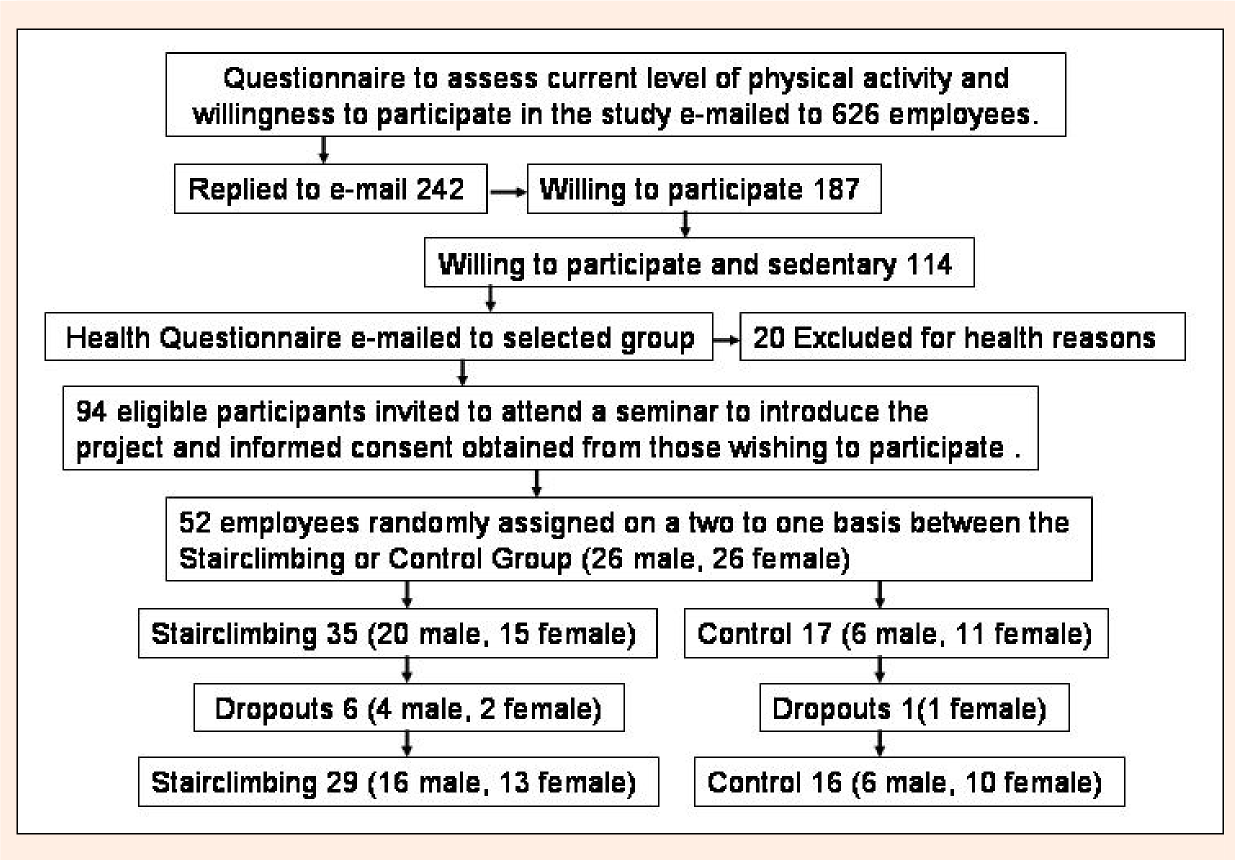

Figure 1. Selection of participants.

previously sedentary adults randomly assigned to stairclimbing or control groups after baseline testing. In accordance with the Declaration of Helsinki for Research Involving Human Beings (American College of Sports Medicine, 1996), the design and performance of each experimental procedure was clearly formulated in an experimental protocol. The protocol was approved by the Research Ethics Committee of the Queen's University of 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 8-wk of training.

Participants

Participants were recruited from employees at a public sector office block. The procedures for selecting and screening for the study are illustrated in Figure 1. In accordance with the ACSM recommendations on non-physician supervised submaximal exercise testing, participants were required to be stratified as moderate risk cases for coronary heart disease (Franklin et al., 2000). Therefore, absolute exclusion criteria for volunteers included known cardiovascular, pulmonary, or metabolic disease. Relative exclusionary criteria included exceeding a threshold of two or more risk factors for CHD and being considered by a supervising physician to be unable to safely complete the required exercise testing and prescription. Participants were required to be non-smokers, not taking any pharmotherapeutic drugs and sedentary i.e. not participating in a regular exercise programme or meeting the minimal physical activity recommendations (U.S. Department of Health and Human Services, 1996).

Assessment of morphological fitness

The measurements of height, body mass and subsequently body mass index were determined using standard methods (Bray, 1978). Percentage body fat was assessed using bioelectrical impedance analysis (Bodystat® 1500; Douglas, Isle of Man) using standard methods (Heyward and Stolarczyk, 1996).

Assessment of cardiorespiratory fitness

Following 5 minutes of rest in a seated position, duplicate measurements of resting blood pressure were made by the same observer using standard methods (Black et al., 1997) with a validated automated sphygmomanometer (Omron HEM-705CP, Washington, U.S.A).

After a habituation session within the testing environment, VO_{2max} was estimated using a sub-maximal multi-stage exercise test on an electronically braked cycle ergometer (SECA, Cardiotest 100, Hamburg, Germany). The YMCA test protocol was used, consisting of two to four, 3-minute stages of continuous exercise designed to raise the heart rate of participants to between 110 beats·min^{-1} and 85% of age predicted maximum in at least two consecutive stages (Golding et al., 1989). Heart rate was monitored by a short wave telemetry system (Vantage NV; Polar Electro, Kempele, Finland). The work rate corresponding to age-predicted maximum (220-age) was determined by linear extrapolation of the sub-maximal heart rate responses, using Microsoft Excel (Microsoft Excel 97, Microsoft Corporation, U.S.A). VO_{2max} was then estimated from the work rate using the ACSM formula for cycle ergometry (Franklin et al., 2000).

Table 1. Morphological and cardiorespiratory fitness at baseline. Data are means (±SD).

	Control (n=16)	Stairclimbing (n=29)
Age (yr)	38.5 (10.7)	44.3 (7.4) *
Height (cm)	163.8 (9.8)	168.8 (9.6)
Body mass (kg)	69.9 (15.0)	72.5 (14.1)
BMI ($kg\cdot m^{-2}$)	25.8 (3.4)	25.3 (3.1)
Body fatness (%)	31.1 (5.7)	26.8 (6.4) *
Systolic blood pressure (mm Hg)	120.5 (13.3)	124.8 (13.6)
Diastolic blood pressure (mm Hg)	77.7 (8.8)	78.6 (8.5)
VO_{2max} ($mL\cdot kg^{-1}\cdot min^{-1}$)	27.1 (3.9)	27.8 (4.9)

* Significant differences between groups ($p < 0.05$).
BMI = body mass index, VO_{2max} = maximal oxygen consumption.

Assessment of metabolic fitness

Venous blood samples (~10ml) were obtained from an antecubital vein after a 12-hour overnight fast with participants lying supine and rested for 5 minutes. Post-intervention samples were obtained 60 hours after each participants' last stairclimb to control for any possible transient effects of physical activity on blood lipid concentrations (Crouse et al., 1997). At pre-intervention blood sampling, all female participants 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 individual's menstrual cycle, minimising the potential effects of endogenous hormones on blood lipid concentrations (Krummel et al., 1993). In the present study, all female participants reported having normal menstrual cycles of between 27-32 days (Gordon et al., 1998).

Within three months, pre- and post-samples were analysed for total serum cholesterol, triglycerides and high density lipoprotein cholesterol (HDL-C) using a Vitros® 950 IRC automated analyser (Johnson and Johnson, U.S.A). The concentration of low density lipoprotein cholesterol (LDL-C) was calculated using the Friedewald formula (Friedewald et al., 1972). All samples were assayed in the same batch, within a laboratory subject to external quality control (United Kingdom National Quality Assurance Scheme). Within batch co-efficients of variation on all tests were <5%.

Exercise prescription

Participants allocated to the exercise group embarked upon an 8-week progressive stairclimbing programme. The programme began with 1 bout of stairclimbing $5d\cdot wk^{-1}$ in weeks 1 and 2, increasing by one climb per day every two weeks until weeks 7 and 8, where a maintenance level of 3 climbs per day was reached. Participants climbed in one of four identical staircases located in the office block, consisting of 145 steps with a total vertical displacement of 23.9 metres. The prescribed exercise intensity involved climbing the 8 flights of stairs at a rate of 75 $steps\cdot min^{-1}$, which was determined in a pre-programme familiarisation session as a comfortable but brisk rate. Participants were instructed to descend the stairs afterwards at their leisure.

To document the completion of each stairclimb all participants kept training logs. Each bout of stairclimbing was integrated into the working day at the convenience of the subject, with a minimum of one hour between climbs. To encourage compliance to the programme and the prescribed intensity of exercise, all stairclimbers underwent once weekly supervised sessions, supplemented by regular telephone calls. All participants were also provided with contact numbers to telephone if they needed help or information. All participants agreed not to change their diet or lifestyle over the experimental period.

Statistical analysis

Changes over time were adopted as a summary measure of the response over time for each subject (Bland, 1995; Matthews et al., 1990). Mean changes were compared using an unpaired t-test to identify differences in response between groups. The 0.05 level was used as criterion for statistical significance. The results are presented as means and standard deviations.

Results

Participants' characteristics at baseline are presented in Tables 1 and 2. There were no significant differences between groups for any variable, with the exception of age and body fatness ($p < 0.05$). Compliance within the stairclimbing group was good, with a mean 88.0 ± 9.2 % climbs completed over the experimental period.

The changes in the dependent variables of interest for the groups over the 8-week intervention period are presented in Tables 3 and 4. Relative to controls, the stairclimbing group showed a significant increase in predicted VO_{2max} ($p < 0.05$). No other significant changes were noted.

Table 2. Metabolic fitness at baseline. Data are means (±SD).

	Control (n=16)	Stairclimbing (n=29)
Total Cholesterol (mmol·L	4.75 (.85)	4.92 (.98)
HDL-C ($mmol\cdot L^{-1}$)	1.19 (.40)	1.00 (.34)
LDL-C ($mmol\cdot L^{-1}$)	2.73 (.80)	2.93 (.74)
TC: HDL-C ratio	4.60 (2.32)	5.55 (2.28)
Triglycerides ($mmol\cdot L^{-1}$)	.85 (.44)	.99 (.55)

No significant differences between groups ($p > 0.05$). HDL-C = high density lipoprotein cholesterol, LDL-C = low density lipoprotein cholesterol, TC:HDL-C = ratio of total cholesterol to high density lipoprotein cholesterol.

Table 3. Changes over time in morphological and cardiorespiratory fitness. Data are means (±SD).

	Control (n=16)	Stairclimbing (n=29)
Body mass (kg)	-.1 (1.3)	+.1 (.9)
BMI ($kg \cdot m^{-2}$)	.0 (0.5)	. (.3)
Body fatness (%)	-.7 (2.3)	-.5 (2.1)
Systolic blood pressure (mm Hg)	-2.2 (3.2)	-2.0 (9.6)
Diastolic blood pressure (mm Hg)	-.2 (3.4)	-2.1 (7.0)
VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$)	+.5 (1.5)	+2.6 (2.1) *

* Change from baseline significantly different from change in controls ($p < 0.05$).
BMI = body mass index, VO_{2max} = maximal oxygen consumption.

Discussion

The findings of this study demonstrate that a low volume stairclimbing intervention can lead to favourable changes in VO_{2max}, but not to improvements in metabolic or morphological fitness among sedentary middle-aged office workers.

In the present study, a significant increase in predicted VO_2max of 9.4% was recorded in the stairclimbing group. Such an improvement is consistent with previous exercise training literature (Pollock et al., 1998) and may appear unexceptional. However, it is noteworthy that this improvement in cardiorespiratory fitness was associated with relatively low volumes of exercise. Stairclimbing training of approximately 6 minutes per day resulted in a similar improvement in VO_2max as walking for 45 min per day (Duncan et al., 1991). Furthermore, continuing this level of training by a further 4-6 weeks has been shown to further improve VO_2max (Fardy and Ilmarinen, 1975), and in the case of very unfit men by as much as 25% (Ilmarinen et al., 1979). It therefore appears that short bouts of endurance training performed at the high end of the intensity zone recommended for cardiorespiratory conditioning (Pollock et al., 1998) can elicit similar improvements in VO_2max as endurance training performed at low-moderate intensities for longer durations. The duration of the training bout may therefore be relatively insignificant to the overall training effect of a programme designed to improve cardiorespiratory fitness relative to the frequency and, especially, the intensity of training (Shephard, 1968).

An inevitable consequence of a sedentary way of life is a low level of cardiorespiratory fitness, thus such individuals have the greatest potential for absolute and relative increases in fitness (Wenger and Bell, 1986). Nonetheless, it continues to surprise many health professionals that low volumes of training such as 30 minutes of exercise once per week (Gettman et al., 1976) or 10 min of exercise 3 times per week will also significantly improve cardiorespiratory fitness in previously sedentary individuals (Wilmore et al., 1970), albeit to a lesser degree. In sedentary individuals the minimum threshold to exhibit a cardiorespiratory training effect is extremely low (Shephard, 1968). Furthermore, a number of studies have examined the training effects of several short bouts of exercise versus one long session per day (Ebisu, 1985; Macfarlane et al., 2006; Murphy and Hardman, 1998; Woolf-May et al., 1999). In relation to changes in cardiorespiratory fitness, limited evidence shows that short bouts are just as effective as those comprising of longer sessions (Hardman, 2001). Therefore, stairclimbing can be promoted within the typical urban working environment as proven method of improving cardiorespiratory fitness in a way that may be more easily incorporated into an individual's lifestyle (Woolf-May et al., 1999).

The health benefits associated with the reported improvements in cardiorespiratory fitness have not always been wholly appreciated (Farrell et al., 1998). Indeed, it was incorrectly assumed that a physically active lifestyle exerted its beneficial effects by simply improving conventional risk factors such as blood pressure, insulin sensitivity, and lipoproteins (American College of Sports Medicine, 1991). However, it has been established that low cardiorespiratory fitness is as strong a predictor of mortality as the more conventional modifiable risk factors, such as cigarette smoking, hypercholesterolemia, and hypertension (Blair et al., 1996; Wei et al., 1999). A number of reports have been published over the past two decades on the relationship between cardiorespiratory fitness and mortality from all causes and cardiovascular disease in particular (Blair et al., 1998; Erikssen et al., 1998). Although the genetic component of the inter-individual variation in VO_{2max} is somewhere between 25% and 40%(Bouchard and Perusse, 1994), the level of physical activity is regarded as the principal determinant of cardiorespiratory fitness (Åstrand and Rodahl, 1986; Powell et al., 1987). Additionally, research findings that report training gains of up to 30% (Holly and Shaffrath, 1998), the rapid detraining related losses (Coyle, 1998) and the natural regression associated with the aging process (Lemura et al., 2000) illustrate not only the plasticity of cardiorespiratory fitness but the requirement of lifelong

Table 4. Changes over time in metabolic fitness. Data are means (±SD).

	Control (n=16)	Stairclimbing (n=29)
Total Cholesterol ($mmol \cdot L^{-1}$)	-.19 (.61)	-.02 (.50)
HDL-C ($mmol \cdot L^{-1}$)	+.09 (.30)	+.14 (.17)
LDL-C ($mmol \cdot L^{-1}$)	-.18 (.59)	-.13 (.49)
TC: HDL-C ratio	-.61 (1.42)	-.79 (1.40)
Triglycerides ($mmol \cdot L^{-1}$)	-.10 (0.27)	-.03 (0.58)

No significant differences in changes over time between groups ($p > 0.05$). HDL-C = high density lipoprotein cholesterol, LDL-C = low density lipoprotein cholesterol, TC:HDL-C = ratio of total cholesterol to high density lipoprotein cholesterol.

physical activity (Lamonte et al., 2000; U.S. Department of Health and Human Services, 1996). In view of the fact that the majority of benefit transpires when an individual moves forward from the lowest to a slightly greater level of cardiorespiratory fitness (Blair et al., 1995; Erikssen et al., 1998), modest amounts of stairclimbing may therefore be one of the most time efficient methods of improving and maintaining the health of sedentary individuals.

There is broad agreement that physical activity has significant effects on CHD risk factors other than VO_2max, such as body mass index, blood pressure and lipoprotein concentrations (Franklin et al., 2000). The volume of exercise performed in the present study was relatively low and of a type that could be easily integrated into many individuals' daily routine, factors that are likely to have the added benefit of greater compliance (Woolf-May et al., 1998; 1999). However, in terms of the effectiveness of stairclimbing to reduce the risk of CHD by improving indices of body composition, blood pressure and lipoprotein concentrations, the results were not supportive. The failure to observe significant changes in these parameters with concomitant increases in cardiorespiratory fitness is in agreement with other physical activity interventions (Asikainen et al., 2003; Grandjean et al., 1996; Hinkleman and Nieman, 1993; Stensel et al., 1994; Woolf-May et al., 1998).

Factors that may explain the non-significant results obtained in the current study are numerous. The most important of these are exercise intensity, duration, frequency, length of training programme, initial fitness level, pre-training lipoprotein levels, weight, body fat percentage, age and gender, and socio-economic factors. Cognisant of these multiple factors, the conclusions drawn must therefore be limited to the population the participants represent and the specific conditions under which the study was conducted (Gaesser and Rich, 1984). Nonetheless, the salient factor appears to be the extremely low training volume. Although the minimum effective volume of training for coronary risk factors such as body composition, blood pressure and lipoprotein concentrations is unknown (Asikainen et al., 2003), it appears to be greater than the estimated 287 $kcal \cdot week^{-1}$ used in the current study (Franklin et al., 2000). The somewhat arbitrary range of 1000-1500 $kcal \cdot week^{-1}$ is gaining some acceptance as a threshold for change (Asikainen et al., 2003; Durstine et al., 2001; Leon and Sanchez, 2001) and is reflected in current physical activity guidelines (Pate et al., 1995; U.S. Department of Health and Human Services, 1996). However, it should be noted that volumes of training as low as 500 $kcal \cdot week^{-1}$ are recognized to have some beneficial effects on all-cause mortality (Kohl, 2001; Lee and Skerrett, 2001) and walking for as little as 60 $minutes \cdot week^{-1}$ has been shown to reduce CHD risk in women (Lee et al., 2001). The optimal pattern of physical activity to obtain health benefits and the associated mechanisms is therefore by no means a resolved issue and has been previously debated (Despres and Lamarche, 1994; Pate et al., 1995; U.S. Department of Health and Human Services, 1996; Winett and Carpinelli, 2000).

Conclusion

In summary, regular stairclimbing selected for its widespread applicability, has been shown to positively enhance an important component of health-related fitness, namely cardiorespiratory fitness. Our findings however do not support the suggestion that a low volume stairclimbing modifies body composition, blood pressure or lipoprotein concentrations in middle-aged men and women and strengthens the argument for additional research into alternative mechanisms that might mediate the effect of stairclimbing on the risk of CHD.

Acknowledgements

The authors thank the participants for their time and efforts.

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Key points

- Low volumes of stairclimbing significantly increased a key component of cardiorespiratory fitness, namely VO_{2max}.
- Stairclimbing can therefore be promoted within the typical urban workplace as a health enhancing activity.
- Indices of morphological or metabolic fitness may require larger volumes of stairclimbing than as prescribed in the current study.

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