STAIR CLIMBING AT HOME FOR HEALTH BENEFITS

By

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ABSTRACT

Climbing stairs is a lifestyle physical activity with effects on a range of cardiovascular disease (CVD) risk factors. This thesis explored the potential of stair climbing at home as a public health intervention in three empirical studies.

A pilot study tested the feasibility of progressive increases in stair climbing and descent at home. Eight participants progressed from 10 floors.day^{-1} in week one to 19 floors.day^{-1} in week four. Percent body fat, systolic blood pressure (SBP) and leg power were improved at the end of the brief intervention. The second study randomly allocated 24 healthy weight [body mass index (BMI = 22.1)] and 26 overweight (BMI = 31.7) sedentary women to gym-based and home-based stair climbing for five days.week^{-1} over eight weeks, with a healthy weight control group recruited for comparison. Intervention participants progressed from two continuous 32.8m ascents.day^{-1} in weeks one and two to five ascents.day^{-1} in weeks seven and eight. Stair climbing improved body composition (weight, percent body fat), cardio-respiratory fitness (estimated $\dot{V}O_2$Max, lactate) and serum lipid profiles [high density lipoprotein (HDL), low density lipoprotein (LDL), Non-HDL cholesterol and triglycerides]. Increases in leg power were found in the stair climbing group. Overall, effects were similar for gym-based and home-based interventions. Given the effects on leg power, and the importance of leg power in the elderly, the third study investigated the potential psychological determinants of increased stair climbing at home for an older population. Participants (n = 281; age = 69.2 years) reported the number of floors that they were willing to climb continuously at home, as well as potential barriers and facilitators of the behaviour. Positive beliefs about the benefits of regular stair climbing and fear of falling,

both on stairs and in general, were the major predictors of willingness to climb stairs at home.

Discussion focuses on the potential of home-based stair climbing as a cost-effective intervention for preservation of function and CVD risk in public health.

DEDICATION

To my family, friends, and to all the

people who have helped me but have now passed away

but still hold a special place in my heart

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PUBLICATIONS

The following two main empirical papers form the basis of this thesis:

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Michael, E., & Eves., F.F. An exploratory study of potential predictors of home-based stair climbing in an older population. (in preparation to submit)

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Eves, F.F., Michael, E., & White, M. (2016). Singapore as an emerging market for health. Department of public health. Singapore.

Eves, F.F., Michael, E., & White, M. (2017). Malaysia as an emerging market for health. Institute of health. Kuala Lumpur, Malaysia.

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a	Value of Significance Level
BMI	Body Mass Index
BP	Blood Pressure
bpm	Beats Per Minute
CHD	Coronary Heart Disease
CI	Confidence Intervals
cm	Centimetres
CMJ	Counter Movement Jump
Cnt	Control
CVD	Cardiovascular Disease
DBP	Diastolic Blood Pressure
DEXA	Dual-Energy X-ray Absortiometry
Exp	Experimental
F	F-value
FES	Falls Efficacy Scale International
HDL	High Density Lipoprotein
HIIT	High Intensity Interval Training
HR_{max}	Maximum Heart Rate
IPAQ	International Physical Activity Questionnaire
kcal	Kilocalories
Kg	Kilograms
L	Litre

lbs	Pound
LDL	Low Density Lipoprotein
M	Mean
m	Meters
MAP	Mean Arterial Pressure
M>F	Males > Females
MET	Metabolic Equivalent
MetS	Metabolic Syndrome
ml	Millilitre
mmHg	Millimeters of Mercury
mmol	Millimole
mph	Miles Per Hour
NHS	National Health Service
MSFT	Multi-Stage Fitness Test
MVPA	Moderate to Vigorous Physical Activity
$MVPA^a$	Moderate to Vigorous Physical Activity Average
n	Number
O_2	Oxygen
p-	Probability Value
PAR-Q	Physical Activity Readiness Questionnaire
PASE	Physical Activity Scale for the Elderly
PP	Pulse Pressure
PRT	Progressive Resistance Training

r	Correlation Coefficient
R^2	Coefficient of Determination
RBP	Resting Blood Pressure
RM	Maximum Repetition
RHR	Resting Heart Rate
RPE	Rate of Perceived Exertion
RR	Relative Risk
SBP	Systolic Blood Pressure
SD	Standard Deviation
SCPT	Stair Climbing Power Test
SE	Standard Error
sec	Seconds
t	Value of T-test
TC	Total Cholesterol
V_E	Minute Ventilation
VO_2	Oxygen Uptake
$\dot{V}O_2Max$	Maximum Oxygen Uptake
WCP170	Physical Work Capacity Test at 170bpm

CHAPTER 1 - INTRODUCTION

1.1. Introduction

It is well known that office work and a sedentary lifestyle have a negative impact on the circulatory and locomotor systems of the human body (Dempsey & Thyfault, 2018). Furthermore, the feasibility of exercising/training during work seems difficult, but not impossible. The “ideal” for these office workers is a type of exercise that will not affect the working time, will be familiar and convenient for employees. The type of exercise needs to be well tolerated, requiring no specialized equipment and no financial cost while providing cardiovascular benefits for most individuals and promoting human health. This thesis addresses one form of exercise which meets these criteria - stair climbing.

1.2. Physical Activity and its Benefits

Physical activity is considered a prerequisite for people to be able to maintain good physical health and prevent various diseases (Boreham *et al.,* 2005). Unfortunately, only a small percentage (≈20%) of most adults in developed countries report participating in any physical activity or fitness changing exercise that can lead to health benefits (Stephard, 1999). Use of objective measures with accelerometry reveals much lower rates. In 2007, 61% of men and 71% of women in England reported that they were less active than the recommended amount to achieve fitness benefits (Health Survey for England 2007; 2008). Objective measures revealed the true level of insufficient activity at 94% for men and 96% for women. In the US, 34% of men and 42% women reported being less active than required. Objective measures revealed similar levels of insufficient activity to the UK (89% men, 91% women; Tucker, Welk & Beyler, 2011). There are many types of activities that take place as part of our daily living, and one of the most vigorous is stair climbing which is a type of exercise that people actually do casually in their own houses or in the workplace. Normally with aging, people can have a loss of the ability to climb stairs and this of course is associated with the loss of muscle mass and leg power, which is a natural consequence of 'unuse' of the human body (Bergmann, Smith & Mayagoitia, 2012). The Department of Health UK (2011), recommends that a person should be physically active for 30 minutes at a moderate intensity at least 5 times.week^{-1}, and that this activity may be performed intermittently throughout the day, in periods lasting not less than 10 min. Brisk walking is considered as moderate-intensity aerobic exercise which increases the heart rate and respiration significantly. This type of walking may last at least half an hour.day^{-1} in a single bout or be performed in three bouts of 10 min.day^{-1} of brisk walking. Vigorous-intensity activities such as jogging would accelerate heart rate more rapidly. As a rule of thumb, one minute of vigorous intensity physical activity is equivalent to two minutes of moderate intensity activity (Department of Health UK, 2011). In addition, it has been suggested that every adult should exercise to improve muscle strength and muscular endurance not on a daily basis, but a minimum of twice a week (Haskell *et al.,* 2007). The latest guidelines also suggest individuals should minimize the amount of time spent sitting for extended periods (Department of Health UK, 2011).

A relatively easy way to meet some of these criteria is the accumulation of exercise during normal lifestyle without the necessity of going to a gym. For example, individuals walk for transport to accumulate of activity. Daily use of private modes of transport such as cars or motorbikes, reduce the amount of physical activity that someone could engage in by using of public transport such as buses and trains. Using public transport requires walking and often some stair climbing which are both beneficial physical activities. Therefore, regular use of public transport could improve the wellbeing of a person through the physical activity required by its use. For example, Morabia *et al.,* (2010) measured an increase of 124 $kcal.day^{-1}$ by switching from cars to the use of public transport to commute in New York.

1.3. Stair climbing as lifestyle physical activity

Stair climbing is a type of physical activity in our daily life, though it seems unlikely that an individual would climb stairs for 10 minutes continuously, i.e. to meet the current recommendation for ten minutes bouts (Bassett *et al.,* 1997). Climbing stairs is a type of exercise that does not require any specific equipment; we can find stairs in almost all public areas and in our homes. Individuals only need to have the internal motivation to use stairs instead of an elevator or an escalator. Intervention studies have found that details of the potential advantages of stair climbing may promote intrinsic motivation for the behavior, e.g. the message "Doctors have found that 7 minutes of stair climbing a day halves your risk of a heart attack over a 10 year period" (Eves, Webb & Mutrie, 2006). It can easily be envisaged that stair climbing is one physical activity that can be easily integrated into daily life by accumulating physical activity throughout the day (Bellicha *et al.,* 2015).

Some epidemiological studies have explored the potential physiological benefits of stair climbing. It has been estimated that an 80kg male climbing a 3m flight of stairs in his house 10 $times.day^{-1}$ would expend about $28kcal.day^{-1}$, which is equated to $10{,}035kcal.year^{-1}$ or to four days without food. Although the behavior itself may appear trivial, this is equivalent to an accumulation of unused energy equivalent to 3lbs of stored fat within a year (Eves, Masters & McManus, 2008; Eves *et al.,* 2009). Indeed, stair climbing interventions that describe calorific expenditure benefits have produced greater effects in overweight participants in a worksite intervention (Eves *et al.,* 2006), an effect recently confirmed in a tram station (Lewis & Eves, 2011).

Thus, daily and regular climbing of additional sets of stairs can, in theory, contribute to weight loss though there is little empirical evidence for this suggestion. Overweight people benefit more from the stair climbing activity because they work more against gravity compared to healthy weight individuals. In effect, they are weightlifting their own body weight (Teh & Aziz, 2002). These facts emphasize the potential benefits of stair climbing, but importantly, relatively little research has explored the level of stair climbing that would have physiological benefits or the extent to which benefits can accrue.

As mentioned before, climbing stairs is an activity that we necessarily do every day (Kerr, Eves & Carroll, 2000). According to Eves *et al.,* (2012) stair climbing is a physical activity accessible to everyone, regardless of background and lifestyle, and does not require any special equipment, clothing or gym membership, unlike sports. It is a habit that people could potentially adopt effortlessly in their daily routine. In addition, Eves *et al.,* (2012, p.9) concluded that “Stair climbing interventions are six times more cost-effective than their nearest rival” based on estimates from Wu *et al.,* (2011). Stairs are a common "barrier" to be overcome in our daily life and an easy to achieve form of physical activity for most of the population. Despite the fact that it is relatively easy for a healthy person to climb the stairs, however, it is contra-indicated when people are facing mobility problems e.g. women during pregnancy, older or obese participants or participants affected by muscle or joint diseases (Riener, Rabuffetti & Frigo, 2002). It is well known that the neuromuscular and biomechanical demands of ascending and descending stairs are greater than during normal horizontal walking. Raising all of one’s body mass against gravity is a metabolically costly behaviour, requiring 9.6 times the expenditure of the resting state in the field (Teh & Aziz, 2002). As a result, stair climbing requires three times the forces of level walking (Reeves *et al.,* 2008; 2009). Therefore, physiological adaptations during stair climbing could be affected by aging as the range of motion and strength decrease. Strengthening these groups of muscles can lead to a safer stair climbing mobility even with aging (Novak *et al.,* 2010).

1.4. Stair Climbing and SCPT (Stair Climbing Power Test)

The Stair Climb Power Test is a clinical measure which is associated with leg power impairments and malfunctions. It is a test that records the mobility in people with lower limb problems and is associated with the mobility performance during stair climbing (Bean *et al.,* 2007). Bean *et al.,* (2007), investigated the significance of the Stair Climb Power Test in older people with mobility problems of the lower extremities. The researchers found that the stair climb power test was associated with mobility performance. This can be applicable for clinical investigations in which mobility relations are of interest and even in people with chronic obstructive pulmonary disease (Roig *et al.,* 2010). Roig *et al.,* (2010), compared the results of the Stair Climb Power Test in people with obstructive pulmonary disease compared to healthy participants. The researchers explored the associations between the stair climb power test and the force generating capacity of the muscles. The protocol of the Stair Climbing Power Test included instructions for ascending 10 stairs as fast as the participants were capable of; and they were allowed to use the handrail only for safety reasons but not use them to ascend the stairs faster. Participants were asked to perform two trials of the Stair Climbing Power test with a minimum period of rest of two minutes. Time, velocity, force and power were calculated. The results revealed that people with obstructive pulmonary disease showed a decrease in the stair climb power test, as well as on measures of functional performance and muscle strength measured with an isokinetic dynamometer, the "Stand Up & Go" test and a six minute walk test. The authors suggested that although the results indicated that this test could not "replace" exercise and therefore the muscle strength protocol, the stair climbing power test was a simple and safe kind of alternative exercise in specific groups such as people with chronic obstructive pulmonary disease or older people for assessing functional performance.

1.5. Interventions for Stair Climbing

1.5.1. Laboratory based studies

A number of studies have shown that stair climbing leads to similar results compared with other forms of aerobic exercise when performed at the same volume and intensity level. Benn, McCartney & McKelvie, (1996) explored the responses of heart rate (HR) and arterial blood pressure (BP) to walking on the level, stair climbing, walking with an upward slope and weight lifting in older males. The findings showed that climbing only three to four flights of stairs at a tolerable pace (50-70 steps.min^{-1}) increases the demands of the circulatory system much more rapidly than 10 minutes of walking horizontally at 2.5 mph, resistance exercise with a ≈14-kg weight or 4 minutes of moderate uphill walking. The results of exercising on an elliptical trainer and treadmill running were equivalent to the positive physiological adaptations produced by stair climbing. Physiological changes, i.e. cardio-respiratory and metabolic improvements, following a 12-week gym based training programme comprised of treadmill running, elliptical exercise and stair climbing, were examined in terms of $\dot{V}O_2Max$ (Maximum oxygen uptake), V_E (minute ventilation), % body fat and maximum workload in non trained middle aged semi sedentary females.

Participants performed three supervised exercise sessions.week^{-1} for 12 weeks, consistent with the intensity guidelines of American College of Sports Medicine; Williams & Williams (1995), for improving cardiorespiratory fitness [week 1 - 4 at 70% - 75% of HR_{max} (maximum heart rate) for 30 min.session^{-1}; week 5 - 8 at 75% - 80% of HR_{max} for 40 min.session^{-1}; and finally week 9 - 12 at 80% - 90% of HR_{max} for 40 min.session^{-1}]. These findings support the fact that laboratory-based interventions that include stair climbing exercise reveal adequate stimulation for developing cardiovascular fitness (Egana & Donne, 2004). Moreover, when comparing stair climbing with run training performance in moderately trained women, Loy *et al.,* (1993) demonstrated that exercising on a stair ergometer reveal similar results with respect to the run workout on a laboratory treadmill or on an outdoor track at relatively equivalent intensities of exercise (Loy *et al.,* 1993). Several studies investigating physical activity and resistance training exercise showed that moderate-intensity workouts that include climbing stairs with other types of exercise, such as walking, can produce many health benefits in adults which would reduce the risk of coronary heart disease (CHD). These studies have introduced stair climbing as a format of exercise, within the laboratory by using structured exercise programmes with specific frequencies, (step.min^{-1}) and repetitions. Leon *et. al.,* (1996) focused on a specific amount of calorie expenditure by exploring the effects of 2.000 kcal.week^{-1} energy expenditure when applying two types of exercises, namely level walking and stair climbing, to explore effects on physical fitness or risk factors for coronary disease. The typical height between floors in a commercial building is 3.5m for each floor; so for the 10 floors involved in the study by Leon *et al.,* (1996) the vertical displacement was 35m.day^{-1}, adding up to 175m each week. Somewhat surprisingly, 12 weeks of moderate walking and stair climbing at an energy cost of 2,000 kcal failed to improve physical fitness. Nonetheless, it can be assumed that the extent of vertical displacement should be the main reference point when assessing the effects of stair climbing. In particular, a vertical displacement of 32.8m for each bout of climbing (not per day as in Leon and co-workers study) was used by Boreham, Wallace and Nevill, (2000) and Boreham *et al.,* (2005). At the end of the intervention, experimental participants were climbing five times a day resulting in a daily vertical displacement of 164m and a weekly displacement of 820m. This volume of stair climbing, considerably more than in Leon and co-workers study, conferred considerable cardiovascular health benefits by altering important cardiovascular risk factors in both studies (see below).

In addition to strength benefits in ageing participants, a study of Fiatarone *et al.,* (1994) explored the benefits of a progressive resistance exercise training protocol in 100 frail nursing home residents. The study showed increases in leg strength in people subjected to long-term care and an improvement in stair climbing power in the exercisers compared to the non-exercisers over a 10-week period. In addition, Jozsi *et al.,* (1999), reported improvements in leg power (≈10% - 30%) in healthy participants (men and women) by using similar methodology and equipment as Fiatarone *et al.,* (1994).

Increased body mass at all stages of human life have increased dramatically in recent decades. Obesity is now considered as a preventable disease and not just an inevitable human condition (Ofei, 2004). Research has suggested that weight loss can be achieved by climbing stairs. A number of studies have investigated the effects of bench stepping on physiological outcomes with obvious implications for potential effects of stair climbing. Specifically, Olson *et al.,* (1991) investigated the metabolic and cardiovascular responses to continuous bouts of stepping exercise, known as aerobic bench stepping or step aerobics in healthy women. Step aerobics was accompanied by music and continuous choreographed movements for 20 minutes on each bench. Participants were asked to perform the protocol of four different bench heights in a cross-over design (B-6 = 6 inches; B-8 = 8 inches; B-10 = 10 inches and B-12 = 12 inches). Results revealed that increased oxygen uptake levels were directly related to the bench height, i.e. B-12 > B-10 > B-8 > B-6. In addition, the amalgamation of 0.91kg hand weights and bench stepping exercise on the 8 inches bench for 20 minutes elicited a statistically significant increase in oxygen uptake compared to the same exercise without hand weights. These findings demonstrated that aerobic bench stepping could enhance aerobic fitness and promote weight loss in healthy women. Further, the greater work required to raise extra weight against gravity could increase energy expenditure when combined with hand weights.

A combination of several forms of exercises, including stair climbing, was conducted by Dreyer *et al.,* 2012 for a 10-week intervention consisting of cycling, stair climbing, treadmill running and weight training. Although it was not just stair climbing, it is important to point out that for the total aerobic exercise per day, participants were asked to train by accumulating 30 Cooper points per week (Cooper, 1986). The weight training session, consisted of four exercises (4-5 sets of four exercises) with a half minute recovery interval between each set. There was a double rotation to repeat those exercises (circuit training). With respect to the physiological variables, systolic blood pressure (SBP), resting heart rate (RHR), pulse pressure (PP), mean arterial pressure (MAP) and VO_2 peak were improved, as well reductions in percentage of body fat, body weight and waist circumference in terms of the morphological variables. Regarding the biochemical variables, serum lipid profiles were improved, with increased high density lipoprotein (HDL) coupled with reduced low density lipoprotein (LDL). Despite these impressive improvements in physiological variables, the relative contribution of stair climbing alone was not established.

1.5.2. Effects of stair climbing interventions in the environment.

Fardy & Ilmarinen, (1975), attempting to assess the benefits of stair climbing, evaluated the impacts and practicability of a stair climbing intervention programme at work. They recruited male employees from an insurance firm in Finland located in a 11 storey building (main stair riser height = 18cm; mean floor height 2.75m). Participants were divided into two groups. The stair climbing group had to ascend and descend stairs when going between floors and the control group was instructed not to use stairs but instead to utilize the lifts. The intervention programme lasted 12 weeks. Surprisingly, when taking the entire stair climbing group into account, the only significant change in the stair climbing group was a decrease of the rear calf skinfold thickness compared to the control group. When the intervention group was divided into subgroups depending on the weekly amount of stair use, the subgroup which ascended and descended stairs the most, i.e. approximately 125 floors.week^{-1} or 344m vertical displacement, showed significantly greater aerobic improvements. The researchers concluded that stair climbing of approximately 25 flights a day for 12 weeks for a 70kg man could improve maximal aerobic power significantly. Thereafter, a 10-week stair climbing training programme took place, exploring the physical working capability of employees during work, comprising 52 voluntary employees in a 31 storey administration building (Ilmarinen *et al.,* 1978). Volunteers were randomly allocated in an intervention group (stair climbing) or a control group (lift for ascent) and they were instructed to climb for 10 weeks at least 25 floors per working day or to use only the lift correspondingly. The amount of climbing equaled 68.7m of vertical displacement each day, assuming that a typical height of each floor was 2.75m as in the previous study. If, however, the floor heights were the more commonly encountered 3.5m, 87.5m of daily vertical displacement would have been achieved. Results showed a significant increase in $\dot{V}O_2$Max and Work capacity fitness test (PWC170) W/Kg for the intervention group (17.8% and 15.1% respectively) compared to the control. The physical work capacity test at a heart rate of 170.min^{-1} is a test on a cycle ergometre that highly correlates to $\dot{V}O_2$Max prediction (Davies & Dagget, 1977). Subsequently, Ilmarinen *et al.,* (1979), attempted to investigate the stair climbing effects during office working hours on women employees, considering that stair use is widespread in urban areas and would be suitable for women employees. In the follow-up study, females improved $\dot{V}O_2$Max with 13 extra floors.day^{-1} over 24 weeks but only significantly so for those at greater risk, the older (+4.8%) and less aerobically fit individuals (+6.3%). Assuming typical floor heights, this would have been equivalent to 45.5m vertical displacement each day, equivalent to 228m each week. This approach to fitness through the stairs is considered advantageous because stair climbing is a universal skill, no equipment is needed and climbing activates the large muscles of the lower extremities.

Boreham *et al.,* (2000), used female volunteers (18-22 years) who underwent a seven week programme of stair climbing, progressing from one bout of stair climbing.day^{-1} (ascent) in week one to six bouts of stair climbing.day^{-1} in the last two weeks (6th and 7th week), using a public access staircase comprised by 199 stairs (32.8m vertical displacement). Controls were asked not to change their lifestyle habits during the research. Regulated climbing tests took place for both groups before and after the stair climbing programme. Heart rate was monitored continuously during a 135 sec paced bout of stair climbing exercise. Blood lactate was measured immediately after each test and serum lipids were measured pre- and post- intervention. Results revealed an increase in HDL cholesterol concentration in the stair climbing group. Heart rate, $\dot{V}O_2$Max and blood lactate were also reduced.

In a follow-up study, Boreham *et al.,* (2005), explored the training effects on several physiological parameters such as total cholesterol (TC) levels, HDL, LDL, homocysteine and maximal oxygen in sedentary young females. Their site for climbing was a public staircase comprised of 199 steps (32.8m vertical displacement). Participants were asked to undergo an 8-week stair climbing programme, progressing from two ascents.day^{-1} in week one and two, five times.week^{-1}, to five ascents.day^{-1} in weeks seven and eight, equivalent to 820m vertical displacement each week. Participants had to ascend at a stepping rate of 90 steps.min^{-1} and each set (ascent) took two minutes for its completion. The findings of the researchers confirmed that accumulated stair climbing throughout the day resulted in statistically significant improvements in $\dot{V}O_2$Max and LDL. This demonstrated that multiple short bouts of stair climbing can produce a reduction of risk factors for disorders such as hypertension and CHD (Boreham el *al.,* 2005).

Kennedy *et al.,* (2007) explored the effects of a low capacity stair climbing intervention at work in office workers living a sedentary life. The 5-week stair climbing programme took place with one bout, five days.week^{-1} in week one, progressing from one climb.day^{-1} every two weeks until week five, by maintaining a level of three climbs each day. Volunteers were asked to climb 145 steps on a staircase of eight floors in an office block at a stepping rate of 75 steps.min-$^{1.}$ The study revealed that, relative to the controls, the experimental group showed a significant increase on $\dot{V}O_2$Max, with no significant changes in serum lipid profiles, blood pressure (BP) and body fatness percentage. These findings resulted from just 30 minutes of stair climbing.week^{-1}, a minimal amount of time exercising during work. Kennedy and co-workers suggested that this type of exercise can be promoted for improving health through physical activity at work because of the relatively low volume required (Kennedy *et al.,* 2007).

Meyer *et al.,* (2010) applied an interesting pre- and post- intervention design for volunteer participants in a 12 storey university hospital building in Geneva. Floor stickers and posters with positive messages to promote stair use were positioned at the point of choice between lifts and stairs at each hospital floor. A 12-week intervention campaign consisted of the volunteers using stairs instead of lifts exclusively to move within the building during the working hours without any special instructions on any desired number of stairs that volunteers had to complete, i.e. the number of ascended and descended stories. Participants were assessed prior to the intervention, at the end of the intervention (12 weeks), and three months after the end of the intervention. After 12 weeks, estimated maximal aerobic capacity was significantly increased, corresponding to approximately 3.5 ml·kg-^{1}·min^{-1} of O_2 (1 MET-Metabolic equivalent). There were statistically significant reductions in fat mass, waist circumference, weight, diastolic blood pressure (DBP) and LDL. At six months, the benefits on estimated maximal aerobic capacity and fat mass remained unchanged compared to the 12 week results. This study showed that encouraging healthy asymptomatic adults to use stairs at work for health was effective in improving lipid profiles, body composition, blood pressure and cardiorespiratory fitness. These are all physiological outcomes that would lead to a reduction in cardiovascular disease (CVD) risk at a population level.

The most recent study exclusive to stair climbing used supervised bouts of climbing and descending equivalent to about five floors. Participants climbed at a relatively high intensity, but nonetheless self-chosen rate, with a rest period in between each combined bout of ascent and descent. The backdrop for the study was an attempt to generalise High Intensity Interval Training (HIIT) programmes from cycle ergometry to the lifestyle physical activity of stair climbing. In the study, healthy, young female participants improved cardio-respiratory fitness with less exercise time than previous studies, equivalent of about two minutes of activity each day (Allison *et al.,* 2017). The speed of climbing at 0.62 $m.s^{-1}$, however, was considerably faster than typically chosen; females in Teh & Aziz (2002) climbed at 0.23 $m.s^{-1}$ whereas, in unpublished data, a younger female sample climbed at 0.34 $m.s^{-1}$ (Eves, Kerr & White, unpublished observations). If the rapid rate of climbing in Allison and colleagues laboratory research is suitable for the general population, reduced CVD risk could be achieved at lower temporal cost than so far has been estimated. It seems unlikely, however, that these high speeds of climbing would be suitable for any elderly cohorts.

1.5.3. Observational studies of the effects of stair climbing.

In a seminal paper, Morris *et al.,* (1953) used occupational role within London Transport to highlight the potential importance of physical activity for coronary heart disease. Comparisons between drivers and conductors on double-decker vehicles revealed that conductors had less coronary heart disease than drivers and that it appeared in them at a later age. In addition, the disease that conductors had was less severe. They concluded that the greater physical activity of conducting, which would necessitate regular stair climbing, was probably protective. Subsequent comparisons between postmen and sedentary office staff confirmed the potential protective role of a physically active job. While these observations of beneficial effects of occupation-based stair usage are intriguing, the cohort design precludes any causal explanations. As Morris and co-workers make explicit, constitutional differences between drivers and conductors or differences in mental strain between the two occupations offer rival alternative explanations for the findings.

An early observational epidemiological study on Harvard male alumni examined the association between physical activity (such as participation in sports, walking, stair climbing and recreational activities) and risk of stroke incidence (Paffenbarger, Wing & Hyde, 1978; Paffenbarger *et al.,* 1986; Lee *et al.,* 1998; Lee & Paffenbarger, 1998). The prospective cohort recruited by Paffenbarger, Lee and colleagues in 1977 were men, 58 years on average during recruitment in 1977, reported at baseline, their frequencies of participating in any kind of sport or recreational activities, walking and stair climbing in a mail survey. Participants were asked to estimate approximately the number of blocks they walked each day, the daily number of flights of stairs they climbed and to record all recreational or sporting activities in which they had participated during the past year. Then, participants were categorized into groups depending on the time spent on any type of physical activity and exercise (weeks.year^{-1}) and duration (time.week^{-1} when active). Then, according to the information given, energy expenditure was estimated during this exercise. Eleven years later (1988), the study followed 11,130 men who had returned their questionnaires or were known to have died by 1990, excluding participants who were diagnosed with CVD or cancer. The results revealed that higher levels of physical activity were associated with decreased risk of CHD and stroke in males. Energy expenditures of 1000 - 3000 kcal.week^{-1} showed a decreased risk, but a U-shaped relation was observed in the data required further explanation. The U-shape relation revealed that energy expenditures of 1000 to 1999 $kcal.week^{-1}$ was associated with a decreased risk of stroke in men, with a further reduction of risk when the energy expenditure was 2000 to 2999 $kcal.week^{-1}$, with no further decrease in risk for higher levels of expenditure. The data also revealed specific protective effects of reported stair climbing volume on CHD and stroke (Paffenbarger *et al.,* 1986: Lee & Paffenbarger, 1998), despite reservations about the accuracy of self-reported stair climbing data (Engbers, van Poppel & van Mechelen, 2007). Despite this measurement caution, protective effects would be consistent with the effects of stair climbing on cardio-vascular disease risk factors outlined earlier. In particular, effects on cardio-respiratory fitness are almost ubiquitous in studies that increase stair climbing (Boreham *et al.,* 2000; 2005; Kennedy *et al.,* 2007; Meyer *et al.,* 2010). Indeed, relatively low volumes of increased stair climbing can improve cardio-respiratory fitness; accumulations of 24 and 21 floors daily improved fitness in Kennedy *et al.,* (2007) and Meyer *et al.,* (2010) respectively. Cardio-respiratory fitness has protective effects for both premature morbidity and mortality. Low aerobic fitness conferred a relative risk (RR) for all-cause mortality more than three and five times that of high fitness levels in men and women respectively (Blair *et al.,* 1989; Blair *et al.,* 1995). Low fitness is a precursor of CVD (Blair *et al.,* 1996); the magnitude of risk on mortality from low cardio-respiratory fitness (RR = 1.52) was estimated as greater than the relative risks from BP (RR = 1.30), high cholesterol (RR = 1.34), high blood sugars (RR = 1.24) and being overweight (RR =1.02). A more recent meta-analysis confirms these protective effects for cardio-respiratory fitness on CVD in longitudinal studies (Kodama *et al.,* 2009). Enhanced cardio-respiratory fitness is what appears to be one of the major mediators of the health outcomes of regular physical activity (Lee *et al.,* 2011).

Many health agencies try to promote stair climbing as a simple exercise for the accumulation daily physical activity as a result of this and other observational evidence. For example, the relationship between stair climbing on a daily basis and body mass index (BMI) in people living in buildings without elevators was examined among 2,846 healthy weight adults in eight European cities (Shenassa *et al.,* 2008). They compared individuals living in single storey buildings with those living in higher rise buildings. Inevitably, the latter subgroup were compelled to climb stairs as part of their daily life. The results revealed that male participants who were resident in buildings with more than one floor had significantly lower BMI than those residents in buildings of less than one floor. Surprisingly, there was no significant association between floor of residence and BMI for women. The latter result may reflect the fact that floor of residence may be a poor proxy for the number of times the stairs are actually climbed.

1.5.4. Environmental interventions for stair climbing.

Physical activity can be integrated into daily activities e.g. during active transport in public access settings and at the workplace. While stairs and escalators are often adjacent in public access setting such as stations, the proximity of stairs to lifts varies widely. Adjacent stairs and lifts are the exception rather than the norm. Typically, when one enters a building, the lifts are prominent visually, being positioned in the centre of the building, e.g. Eves, Webb & Mutrie, (2006). In contrast, stairs are often hidden to the side of the lifts (Eves *et al.,* 2006) or require a short walk to locate them, e.g. Marshall *et al.,* 2002). In many buildings, the main function of stairs is to provide an escape route in case of fire and typically, signage for the stairs indicates that they are the way out in case of a fire. Often they are hidden behind closed doors, e.g. Bungum, Meacham & Truax (2007), and may even require a key card for access as a security measure, e.g. (Boutelle *et al.,* 2001). As a result, signage to locate the stairs for lift users is usually introduce as part of any intervention, (e.g. Eves *et al.,* 2006; Marshall *et al.,* 2002) and it has been reported that there are greater effect of intervention in buildings where the stairs are hidden behind doors (Bungum *et al.,* 2007).

Many quasi-experimental studies have shown the impact of posters that are placed at the point-of-choice between escalators and stairs in public access settings such as shopping malls and train stations (Brownell, Stunkard & Albaum, 1980; Blamey, Mutrie & Aitchison, 1995; Andersen *et al.,* 1998; Eves *et al.,* 2006; Eves *et al.,* 2008; Eves *et al.,* 2012). Typically, a poster is placed at the point-of-choice encouraging individuals to choose the stairs for a health benefit, e.g. weight control. These studies have shown that by encouraging people to exercise more or even to begin exercising if they are sedentary, greater benefits could be available. Population strategies on lifestyle interventions such as using stairs instead of escalators aim to reduce the level of CVD risk at a population level. It is well known that physical activity is protective for the risk of CVD. In this respect, vigorous activity such as stair climbing should confer more protection than activity of moderate intensity (Yu *et al.,* 2003; Janssen & Ross, 2012; Laursen *et al.,* 2012).

One influential quasi-experimental study aimed to increase stair climbing by placing multiple stair riser banners on the stairs at the point-of-choice between using stairs and escalators in a shopping mall. The banners were placed on the vertical riser of the stairs to be visible at the time the choice was made (Kerr *et al.,* 2001a). These banners contained multiple motivational messages such as “Take the stairs.” “Keep fit,” “Daily exercise,” “Work your legs,” “Free exercise” “Stay healthy,” “Easy exercise,” “Be active,” and “Exercise your heart". The total duration of the study was 24 weeks and the follow up period included the last eight weeks. Results showed a sustained increase of the use of stairs after placing posters on the stairs an increase which persisted, even after posters were removed during the follow up period. There was a more than doubling of stair use which remained sustained over a 3-month period. The strongest initial response to stair use due to the motivational messages was shown by women under 60 years of age. Nonetheless, only those estimated to be over 60 years of age showed an incremental response during the intervention such that stair use in the second half was increased relative to the first half of the intervention. A similar study by Kerr *et al.,* (2001b) tested motivational messages in terms of their visibility. It was concluded that colourful banners rather than simple posters should be used to encourage stair climbing as there was a two-fold greater response with the banners that was consistent with their greater visibility (79% vs 33% for posters).

A recent study by Lee *et al.,* (2012), explored the effect of posters in various buildings and on stair ascending and descending. The poster contained the following messages: "Burn calories, not electricity!" – "Take the stairs!" "Walking up the stairs just 2 minutes a day helps prevent weight gain, it also helps the environment!". After posting the prompt, stair use was increased in all the buildings. Furthermore, the authors reported that physical activity remained increased over the 9 month study period. A study by Lewis & Eves (2012), investigated the importance of volitional and motivational components of stair climbing intervention in workplace. The motivational component was the reason that encouraged people to try stair climbing providing them with a reason to act in a certain way such as stair climbing. The extended text, "Stair climbing always burns calories. One flight uses about 2.8 calories but 10 flights a day would use 28 calories. Over a year that adds up to 10,000+

calories; that's more than three pounds of fat" aimed to encourage visitors to the buildings to consider stair climbing as a means of weight control. The volitional component was the short message "Stair climbing always burns calories" as a point-of-choice prompt above the lift button. The aim here was that information was located at the time and place where people had to decide the method they had to choose to ascent. The authors reported that if the motivational component was positioned alone in a lift, there was no increase in stair climbing. When both components were positioned together (volitional and motivational) then the use of stairs was significantly increased. As with interventions in public access settings, visibility at the time choice is made is the key to intervention effectiveness in workplaces.

1.6. Stair climbing, bone health, leg power, leg strength and falls risk

Osteoporosis, a weakening of the bone structure, is a particular "threat" from ageing for menopausal and postmenopausal women (Meng-Xia, & Qi, 2015), but osteoporotic fractures also affect men Epidemiological evidence has shown that, apart from medication against it, osteoporosis could be controlled or even be reversed through habitual physical activity and exercise (Nikander *et al.,* 2010). There is a strong association between historical levels of stair climbing/brisk walking and bone mineral density in postmenopausal women (Coupland *et al.,* 1999). Both types of lifestyle activity in a cross-sectional study revealed positive independent associations in bone mineral density of the whole body and especially at the trochanter hip site (Coupland *et al.,* 1999). Jakes *et al.,* (2001) investigated ultrasound attenuation in the heel bone for males and females in relation to the patterns of physical activity performed during their daily activities. Ultrasound attenuation is an index of bone health, with low levels of attenuation an indicator of low bone mineral density and therefore susceptibility to bone fractures. While bone density had been associated with physical activity, it was unclear how the differentiation of physical activity could affect the achievement of a greater bone mass or its gradual decline occurring during ageing (Layne & Nelson, 1999; Wolff *et al.,* 1999). Low impact activity such as conditioning exercises, rowing and sailing, cycling and swimming, as well as moderate impact activity such as walking for pleasure and golf, had no effect on bone mass (Jakes *et al.,* 2001). In contrast, the high impact activities such as step aerobics, jogging and tennis were related to bone health (Jakes *et al.,* 2001).

Stair descent is a high impact activity compared to level walking. When descending stairs, we have to break the fall of our weight against the effects of gravity. While stair climbing has the same ground reaction forces as walking on the level (Spanjaard *et al.,* 2007; 2008; 2009; Reeves *et al.,* 2008), ground reaction forces are greater for descent than ascent because the centre of mass falls further onto the leading leg placed on the step below. While Jakes and co-workers reported that the number of flights of stairs climbed was significantly associated with ultrasound attenuation in women, a flight of stairs climbed is typically also descended. There was more attenuation, i.e. better bone health, for each additional five flights of stairs. It was concluded that ultrasound attenuation in the heel bone in both males and females was independently associated with high impact daily exercise (Jakes *et al.,* 2001). Consequently, preservation of bone mass density may be promoted by the high impact activities of stair use. Repeated climbing and subsequent descending at home could be beneficial in this respect.

It is well established that "power is a physiological variable related to strength and associated with the ability to perform muscular work per unit of time", i.e. briskly or rapidly

(Bean *et al.,* 2002, p.1). When referring to stair climbing, the relationship between generating force quickly when ascending and descending stairs is a factor that can be used to stimulate physiological adaptations especially in elder life. This is an important topic concerning gerontology, because muscular power decreases more rapidly than strength in older people (Metter *et al.,* 1997). Moreover, it has been shown that progressive resistance training (PRT) using any type of exercise improves muscle power in elderly people with mobility problems (Fiatarone *et al.,* 1994; Jozsi *et al.,* 1999).

Stair climbing while carrying extra weight may be one potential form of home-based power training. Researchers have shown that weighted vest exercise in older people produces benefits in bone mass, power and even in body balance (Cress *et al.,* 1991; Shaw & Snow, 1998; Snow *et al.,* 2000). More specifically, weighted stair climbing exercise enhances muscle strength, range of motion and muscle function in healthy elderly people (Rooks *et al.,* 1997; Shaw & Snow, 1998). Moreover stair climbing exercise using a stair climb machine produces increased responses in heart rate and systolic and diastolic blood pressure, which are greater than other types of cardiovascular exercise such as walking (Benn, McCartne & McKelvie, 1996). These effects reflect the vigorous nature of the physical activity being performed. Leg strength and power are important requirements for climbing stairs. Andriacchi, Andersson and Fermier, (1980), established that the ability to climb stairs depends on the extension of the hip, which is equivalent to the muscle action of the leg press usually performed in the gym, while larger knee extension forces are generated when descending stairs.

Bean *et al.,* (2002), explored the effects of weighted stair climbing exercise on the power of the lower extremes in mobility-limited older participants. Participants were randomly placed into one of two exercise programmes which lasted 12 weeks. The intervention group was asked to ascend and descend stairs at a specific set pace while wearing a weighted vest and the control group was participating in a specific walking programme: participants had to wear a weighted vest with an audible metronome attached to the vest, assigned to a stepping pace corresponding to the target training pace. During each exercise session, participants had to ascend and descend 12 flights (126 steps), divided into three sets of four flights, with a resting period of two minutes between each set. There were increments in the weight carried in the vest by 2% of the participant's body mass if they were capable of completing all the sets according to the target training pace. The study assessed measures of sub-maximal aerobic capacity, muscle power and strength as well as physical performance. There was an improvement in sub maximal aerobic performance for both groups. Although not statistically significant due to a relatively small sample, effect size estimates suggested that stair climbing exercise increased strength, knee extension and power. Both groups showed an improvement in stair climbing time, whereas stair climbing exercise produced significant improvements from baseline in a subgroup of volunteers. According to Bean *et al.,* (2002), the essential result of this study in older people with mobility problems was that weighted stair climbing showed that leg press power and stair climbing power were significantly increased compared to a standard walking programme. Bean *et al.,* (2002), suggested that ascending stairs is not considered as the first choice for exercise in older people. In contrast to a stair climbing machine where the resistance is constant, and is determined by the rate set by the participant, the process of ascending and descending stairs includes a phase with a reduction of workload, which occurs during descending, when eccentric leg muscle contractions predominate. Thus, with natural stair use there is a coexistence of concentric and eccentric muscle activation of the lower extremities during the same exercise.

In the only nationally representative sample assessing cardio-respiratory fitness in the UK, increasing age was associated with reduced fitness and leg strength (Allied Dunbar National Fitness Survey, 1992). Longitudinal studies confirm a progressive loss of leg strength as male and female participants get older (0.8% and 0.7% respectively) with yearly declines typically revealing large effect sizes, i.e. Cohen's d>0.8 (Koster *et al.,* 2011). As outlined earlier, loss of leg strength, or more correctly its functional manifestation as leg power, can contribute to limitations in everyday living. For example, leg power has been related to walking speed, timed rising from a chair and rate of stair climbing in the elderly, all measures that can indicate functional limitations in an ageing population (Bean *et al.,* 2002a). Physical activity and physical performance is related to incidence of falls and falls risks in the elderly. Chan *et al.,* (2007) examined the relationship between physical performance and falling incidence in a large population of 5,995 community males in the United States of at least 65 years of age. Participants completed the Physical Activity Scale for the Elderly (PASE), a 12-item questionnaire of self-reported household, occupational activities and leisure items commonly engaged in by individuals aged 65 and older. The study lasted for five years (2000-2005). The frequency of falls was obtained from up to seventeen questionnaires per participant, with data collected three times a year. The authors explored which types of activities were associated with fall risk and whether activity and performance reduced risk. Men with greater lower limb power and grip strength had a significantly reduced risk of falling. Regarding the modality of activity, there was no association between fall risk and leisure activities but a negative association between falls risk and participation in household activities, the latter including stair climbing and stair descending. Thus, stair use at home may be an attainable and feasible form of exercise for promoting health to both women and men. The activity may be performed during normal lifestyle within the house. As outlined earlier, stair climbing is a form of exercise that strengthens the legs due to the need to raise all of one's own body weight against gravity. Greater power in the lower limbs from stair climbing, i.e. increase in quadriceps strength (Loy et al., 1994), could lead to a reduced fall risk whereas the subsequent stair descent could contribute to high impact activities that improve bone health.

In an early laboratory-based stair climbing protocol, sedentary middle age females climbed on a stair-master four days.week^{-1} for 12 weeks (Loy *et al.,* 1994). Increases in quadriceps strength were reported, as well as improved cardio-respiratory fitness. In the only environmental intervention, (Donath *et al.,* (2014) formally investigated the effects of increased stair climbing in an elderly population (70.5 years old). Over an 8-week period, participants climbed stairs in an eight floor, multi-story parking garage three times a week. The total vertical displacement of each climb was 21.8m. As with previous stair climbing interventions by Boreham and co-workers, there was a progressive increase in the number of climbs, starting with two climbs per session in weeks one and two and progressing to five times per session in weeks seven and eight. At the end of the intervention, participants were on average completing 326m of vertical displacement.week^{-1}. One group of experimental participants climbed two stairs at a time while the other group climbed at one stair per step. Participants were instructed to descend in the lift so that any effects of the higher impact activity were precluded. Although significant increases in strength for unilateral and bilateral leg press relative to the control group occurred, these effects did not survive adjustment for baseline covariates. Nonetheless, Donath and co-workers made explicit that the effect sizes for changes in strength were of at least moderate magnitude. In addition, there was an improvement in functional balance performance such that walking on a 4.5cm beam was improved for the group using the two-step strategy, with marginally significant improvements for the same group when walking on a 6cm beam. Consistent with earlier summaries of effects of stair climbing on cardio-respiratory fitness, improved functional fitness occurred such that reported effort, heart rate and lactate increases during uphill walking (8% slope) were attenuated after the intervention. These data are suggestive that stair climbing could serve as a strength training and balance intervention for an older population. Due to two major interacting factors of muscle weakness and impaired balance, the potential effects of stair usage on the risk of falling in this population would be of considerable interest. Any home-based approach to stair usage could avoid problems with any reduced ability of older people to visit a gym due to functional limitations.

Gardner *et al.,* (2001) modified a simple exercise programme for strengthening and balance retraining for older people; subsequent to a randomized controlled study in 80 year old women and older to prevent falling (Campbell *et al.,* 1999). This study successfully reduced falls and subsequent injuries in people aged 80 years and older over a 2-year period supervises by an exercise instructor (relative hazard for all falls for the experimental group was 0.69). In addition, Clemson *et al.,* (2012) used a simple lifestyle approach to falls risk to explore if there was a decrease in rate of falls in older people after integrating some balance and strength training into their daily life activities, though stair usage was not formally included. The results were encouraging longitudinally; there was a significant reduction in falls (31%) for what was termed the ''lifetime integrated functional exercise group'' compared to the controls for adults over 70 years of age. It is possible that with some extra stair climbing integrations, fall risk could be decreased further by increasing balance performance and power of the lower limbs.

1.7. Weight change

There is insufficient literature demonstrating a statistically significant change in body weight when following regular stair climbing. As noted earlier, theoretically weight loss should be achievable by climbing stairs; over a year, ten extra floors a day represents energy expenditure equivalent to 3 lbs of fat. Studies by Boreham *et al.,* (2000); Boreham *et al.,* (2005) and Kennedy *et al.,* (2007) did not report any changes in weight in controlled studies. The solitary evidence for changes in weight, waist circumference and body fat comes from the uncontrolled study of Meyer *et al.,* (2010). In another uncontrolled study of climbing, Tian *et al.,* (2015) asked individuals to climb 436m on a fixed route up a hill at their chosen velocity, once per week for 16 weeks. Whereas males showed a significant reduction of body weight and fat mass, the reduction in fat mass in females was accompanied by increases in fat free mass resulting in no overall change in body weight. In a related observational study, Shenassa *et al.,* (2007) reported a lower BMI in males who lived on the upper floors of buildings relative to those living on the ground floor whereas similar effect of height of residence was not found in women. Bassett *et al.,* (1997) estimated the gross caloric costs of ascending escalator steps of 20.3 cm at 0.15 $kcal.step^{-1}$ and descending stairs at 0.05 $kcal.step^{-1}$. For the lower, but more typical, riser heights of 15 cm, Teh and Aziz (2002) estimated costs of 0.11 $kcal.step^{-1}$and 0.05 $kcal.step^{-1}$ for ascent and descent respectively. When estimating the calorific costs of climbing in the built environment, Eves, Olander, Nicoll, Puig Ribera & Griffin (2009) used the METs cost of ascent from Teh & Aziz

(2002) allied to the average speed of climbing in the train station, 0.302 $m.s^{-1}$, to estimate that an 80 kg individual would expend 0.916 $kcal.m^{-1}$ of ascent. Overall, there are no studies with convincing evidence of experimental effects of stair climbing on weight and body fat though there is some suggestive positive evidence.

1.8. Summary of physiology of stair climbing

The human body utilizes muscles both eccentrically and concentrically during daily activities. Concentric contractions occur when the muscles shorten whereas eccentric contractions occur when the muscles lengthen against load. Concentric and eccentric contractions are regularly used when ascending and descending stairs (Gur *et al.,* 2002). The agonist muscles executes joint contractions concentrically, i.e. shortens, if a movement acts against the pull of gravity. Concentric contractions will be required when climbing. In contrast, the agonist muscles contract eccentrically and lengthen when stair descending under the pull of gravity. In terms of stair ascending, the quadriceps muscles shortens, contracts concentrically, whereas in stair descending the leg quadriceps muscle lengthens (Gur *et al.,* 2002; Padulo *et al.,* 2013; Hessel *et al.,* 2017;).

In essence, walking is controlled falling. During forward motion, when the centre of mass is moved outside the support foot, it falls under gravity onto the leading leg in front of it. Typically, the vertical ground reaction forces for level walking are around 1 N.kg-1, with symmetrical forces on each leg (McFadyen & Winter, 1988; Riener, Rabuffetti & Frigo, 2002). Stair climbing is associated with similar ground reaction forces, about 1 N.kg-1 on both the leading and trailing legs (Riener, Rabuffetti & Frigo, 2002; Reeves *et al.,* 2009). For stair descent, however, the forces are greater because the centre of mass falls further onto the leading leg placed on the step below. The vertical ground reaction force on the leading leg is about 1.5 N.kg-1, with elevation also for the force on the support leg to about 1.3 N.kg-1 as the centre of mass falls under gravity (Riener, Rabuffetti & Frigo, 2002; Reeves *et al.,* 2007).

Concerning effects on the cardiovascular system, Bassett *et* al., 1997) measured oxygen consumption with the Douglas bag technique while relatively young students (25 years old) ascended and descended an escalator at 70 steps.min-1. They reported that ascent required 8.6 METs, whereas stair descent required 2.9 METs. Nonetheless, the riser height of a typical escalator step, ~ 20.3 cm, is higher than steps found in the built environment, 14 - 18 cm. As such, escalator steps better suit minimization of energetic costs as they are closer to a riser height that is the quarter of leg length that minimizes costs when climbing (Warren, 1984). Unpublished data confirm Bassett and co-workers estimate when climbing on a stairmill in the laboratory with a riser height of 20.3 cm. Aerobically fit students (22 years old) , i.e. those who played team sports at least three times per week, required 8.7 ± 0.6 METs when climbing at 60 steps.min-1 (n = 16: Eves & White, unpublished). The climbing rates in these studies, 0.236 m.s-1 and 0.203 m.s-1 for Basset *et al.,* (1997) and the unpublished data of Eves & White respectively are considerably slower than pedestrians normally adopt when climbing in the built environment. Observational data in a shopping mall revealed that pedestrians climbed at 100 steps.min-1, equivalent to a speed of 0.283 m.s-1, 95 % CI = 0.272, 0.296 (n = 147: Webb, Eves & Smith, 2011). A field study by Teh & Aziz (2002) where 44 years old individuals climbed at 95 steps.min-1 on steps with a riser height of 15 cm estimated costs of 9.6 METs for ascent and 4.9 METs for descent, somewhat higher than the escalator based study of Bassett and co-workers (1997). In all of the above studies, participants climbed one step at a time. Often in the built environment, individuals will climb two steps at a time rather than taking a single step. Halsey, Watkins & Duggan (2012) used heart rate calibrated against oxygen consumption to estimate costs of the different stepping strategies for a 16.3 cm riser height. They estimated that climbing with a one step strategy at 91 steps.min-1 cost 8.5 METs whereas the two step strategy at 56 steps.min-1 cost 9.2 METs. As the two step strategy resulted in a quicker climb of the staircase, 0.304 m.s-1 vs. 0.247 m.s-1, costs were increased. Nonetheless, all of the above estimates for climbing are within the range 9.6 – 8.5 METs, i.e. a vigorous physical activity, despite differences in the speed of climbing. While the speed of climbing will influence costs of that climb, the major cost is incurred when raising body mass against gravity.

Unsurprisingly, given the vigorous nature of the physical activity, stair climbing challenges the cardiorespiratory system. A sedentary individual climbing stairs will reach 85% of heart rate maximum after one minute of continuous climbing at 88 steps.min-1 (Boreham *et al.,* 2000). As a result, increases in stair climbing on a weekly basis improve cardiorespiratory fitness. The pioneering studies of Ilmarinen and co-workers both reported evidence of improved aerobic fitness, i.e. V̇O2Max (Fardy & Ilmarinen, 1975; Ilmarinen, Ilmarinen, Koskela *et al.,* 1979). All subsequent studies confirmed improvements in indices of aerobic fitness for inactive participants at baseline (Allison *et al.,* 2017; Boreham, Wallace & Nevill, 2000; Boreham, *et al.,* 2005; Kennedy, *et al.,* 2007; Meyer, Kayser, Kossovsky *et al.,* 2010).

For other cardiovascular risk factors, the evidence is more mixed, but encouraging effects for lipoproteins have been found. Boreham et al (2000) reported reductions in total cholesterol and HDL cholesterol in stair climbers whereas a subsequent study by this group reduced LDL cholesterol but had no effects on total cholesterol, HDL cholesterol or triglycerides (Boreham *et al.,* 2005). A further study with a lower accumulation of weekly stair climbing did not change any lipoproteins (Kennedy *et al.,* 2007). In addition, an uncontrolled study reported reduction in LDL but, like Boreham and co-workers in 2005, had no significant effects on total cholesterol, HDL cholesterol or triglycerides (Meyer *et al.,* 2010). The latter study also reported the only reductions in diastolic blood pressure and body fat in this research area, despite tests for effects on weight and body fat in other studies (Allison *et al.,* 2017; Boreham *et al.,* 2000, 2005; Kennedy *et al.,* 2007).

The main purpose of this thesis is firstly to test the effects of stair climbing on several physiological variables, namely cardio-respiratory fitness, resting cardiovascular variables, body composition and lipoprotein profiles. Given the mixed evidence for effects on lipoproteins with relatively small samples (Boreham *et al.,* 2000, 2005), we set out to test a larger sample than previously employed in an attempt to provide definitive evidence for effects on these cardiovascular disease risk factors. As noted in the summary, only one study provided evidence for effects on body composition. To further address this question, effects of stair climbing were tested in sedentary healthy weight and overweight samples. The second major question was to assess whether using stairs at home to increase stair climbing would have equivalent effects to stair climbing in a gym setting. Stair climbing at home would avoid the logistical problems associated with gym-based exercise as well as providing a low cost exercise intervention. While previous studies have examined health related outcomes by from stair climbing, the essential question here was ''does home based stair climbing produce physiological benefits?''. If it could be shown to reduce cardiovascular disease risk, home-based stair climbing would provide a cost effective exercise for public health. The final study set out to explore potential psychological factors that might influence the willingness of an older population to increase stair climbing at home. Home-based stair climbing may be a plausible exercise for older individuals. Nothing was known previously on this question. Therefore, we set out to explore both positive and negative specific outcomes of stair climbing, and a potential barrier fear of falling, as potential determinants of willingness to climb in an older population. The aim was to assess attitudinal statements about the outcomes of stair climbing that might be relevant to any intervention materials.

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CHAPTER 2 - PILOT STUDY FOR A HOME-BASED STAIR CLIMBING PROGRAMME

2.1. Introduction

To evaluate the practicality of a study it established that a pilot study design needs to be conducted before performing a full-scale research study. A mini-version of the full-scale study is expected to reveal how well future studies will occur because the first step of the practical implementation will be performed. The pilot study warns us what can go wrong and guides us to reasonable thoughts for modifications or amendments for successful future research.

In a pilot study, measurement techniques should be tested to minimize possible errors and to identify any practical issues of the research procedure. For this research, the pilot study was deemed necessary because some simple measures needed to be tested before the blood analysis and fitness levels of the main empirical study. In addition, the study was to be performed in private homes of the participants, a fact that makes the research potentially problematic since, in most cases, the participants were not to be supervised by the researcher. Therefore, the pilot study was deemed important to indicate whether proposed methods are appropriate when the participants would not be following instructions from a supervisor in situ.

As it is clear from the introduction, stair climbing is the topic of this research regarding aspects of cardiovascular physiology, by examining possible changes in the human body when climbing stairs as a daily exercise.

The pilot study design was a simple pre- versus post- comparison in a single group.

2.2. Methods

2.2.1. Participants

Initially, 10 participants (5 females and 5 males) were recruited to the intervention programme. Two participants were excluded as they were overweight (Body mass index - BMI>25) so the final sample size was n=8 (4 males and 4 females). All of them were healthy adult students recruited from the Limassol College in Cyprus. The recruitment process was initially through electronic mail and interviews were arranged for individuals who were interested to participate. Volunteers were selected according to their BMI (≥20, ≤25,). Inclusion criteria were age 20-30 and no contra-indication for an exercise programme. Data on medical history, medication use, habits and anthropometric characteristics were obtained by using a standardized questionnaire (Physical Activity Readiness Questionnaire - PAR-Q). Volunteers were asked not to change their diet or lifestyle over the experimental period. Travelling expenses were paid to participants but no other monetary encouragement to participate was provided. If any of the participants felt uncomfortably they had the right to withdraw. Ethical approval was obtained from the University of Nicosia ethics subcommittee. Participants characteristics are shown in the table below.

Table 2.1. Characteristics of participants at baseline

Sample size	No. (n =8)
Age	21.37±1.68
Height, m	1.71±0.11
Weight, kg	65.8±16.33
BMI (kg/cm^2)	22.02±2.75
Body fat %	20.98±3.54
Systolic BP, mmHg	124.25±4.13
Diastolic BP, mmHg	79.50±2.67
Vertical jump (cm)	43.75±16.14

Statistics for continuous measures are shown as mean ± SD.

2.2.2. Protocol and Equipment

The protocol included the following measurements prior to the intervention:

- Anthropometric characteristics (fitbit Aria Scale)
- Skinfold calibration (Harpenden Skinfold Caliper)
- Resting heart rate (RHR) (Life source A&D Medical UB-328 Blood pressure (BP) Monitor)
- Resting blood pressure (RBP) measurements (Life source A&D Medical UB-328 BP Monitor)
- Power of lower limbs by vertical jump (equipment required: measuring tape and marked wall, chalk for marking wall).

2.2.3. Procedure for the vertical jump

The participant stood side on to a wall and reached up with the hand closest to the wall in light indoor clothing according to the researcher's instructions. Keeping the feet flat on the ground, the point of the fingertips was marked and recorded. This is called the standing reach height. The participant then stood away from the wall (~ 20cm), and leapt vertically as high as possible using both arms and legs to assist in projecting the body upwards. The jumping technique used a countermovement. Participants attempted to touch the wall at the highest point of the jump whereas the height reached when jumping was recorded with chalk. The score was the difference in distance between the standing reach height and the jump height. Participants underwent three attempts and the best one was recorded.

2.2.4. Measurement of skinfolds

Body mass and height were determined using the FitBit Aria Scale and BMI was then calculated as used by the World Health Organization (2010). Body fat percentage was calculated by the sum of seven skinfolds (thigh, abdominal, suprailiac, subscapular, midaxillary, chest and triceps) according to the generalized equations for predicting body density of men and women (Jackson, Pollock & Ward 1980; Jackson & Pollock, 2004).

All of the procedures took place in the Spyros Kyprianou sports centre in Limassol, Cyprus.

2.2.5. Intervention Programme

The intervention for this pilot study was separated into four parts.

In general, participants were asked to record the specific amounts of stairs ascended but not to count the descended stairs in a row. Specifically, they had to add an extra target of 120 steps upwards to their daily use of stairs. This was to be increased each week according to the follow programme:

1st week: 120 steps.day^{-1} (equals to 10 flights of 12 steps)

2nd week: 156 steps.day^{-1} (equals to 13 flights of 12 steps)

3rd week: 192 steps.day^{-1} (equals to 16 flights of 12 steps)

4th week: 228 steps.day^{-1} (equals to 19 flights of 12 steps)

Measurements of the stair height of each participants house was not considered as necessary at this stage of our study because we were exploring the willingness to climb stairs at home. However, the number of stairs climbed for each individual for the follow up studies will be described in the discussion section.

One week after the intervention programme, the measurements were repeated.

2.2.6. Statistical analyses

A paired t-test was used to compare the means for the measures from two related samples. The value of significance level of $\alpha = 0.05$ was set.

2.3. Results

Table 2.2 contains paired pre- and post- measures of weight, % body fat, systolic blood pressure (SBP), diastolic blood pressure (DBP) and vertical jump height.

Table 2.2. Mean pre-post measures of weight, % body fat, systolic blood pressure, diastolic blood pressure and vertical jump.

	Mean-pre (SD)	***Mean-post (SD)***	***t-value***	***p-value***
Weight (kg)	65.85 ± 16.33	66.87 ± 16.03	2.508	.041
% Body fat	20.98 ± 3.54	19.6 ± 3.4	8.238	<.001
SBP(mmHg)	124.25 ± 4.13	122.8 ± 3.44	2.582	.036
DBP(mmHg)	79.5 ± 2.67	78.62 ± 1.76	1.142	.291
Vertical jump (cm)	43.75 ± 16.14	46.12 ± 16.37	3.800	.007

On average, there was a statistically significant increase in weight after the intervention programme. In contrast, a statistical significant reduction in the % of body fat after the intervention programme was also found. Participants showed a reduction in SBP after the intervention programme. Diastolic blood pressure was also decreased but not significantly so. Participants showed significant higher vertical jump after the intervention programme suggesting an improvement in performance.

2.4. Discussion

As can be seen from the results, there were significant reductions in % of body fat, SBP and a significant increase in weight and vertical jump. Results showed there was no statistical significant reduction in DBP. Therefore the hypothesis for significant differences was accepted for most of the variables examined.

The results of this pilot study were encouraging. Informally, participants reported an enthusiastic willingness to participate because they were impressed by the fact that they could undergo a training programme without paying or need to go to the gym. Additionally, they were interested to learn about their body composition since they had been told that the results would be given to them after the termination of the study. The students had no trouble completing the protocol, with a small exception during the final week of the study, where one participant was complaining about feeling some muscle stiffness and fatigue. Some informal comments of the participants at the end of the programme were *'Sometimes it was boring but I did it', 'I never thought that I can do this in my house', 'I saved 60 euro for this month just because I was practising at home and not at the gym'*, were encouraging for the study. This study illustrated that increased stair climbing at home was feasible even without supervision. Nonetheless, the sample included young students who showed willingness and desire to exercise. It is unknown if it will be similar for older participants or people who are unhealthy. In general, there is usually not much incentive and desire to increase fitness when at home. For many people, it seems unusual to practice at home but, clearly, there are people for whom this kind of fitness suits. By having stairs at home is as if having a multifunction type of training machine for potential beneficial effects on people's health.

From the results it is clear that there was a statistically significant difference in most of the variables after the intervention stair climbing programme. Surprisingly, as some participants put on weight, despite a loss of body fat, it is clear that there was a separate training effect that might not be expected from climbing stairs alone. This finding could be further explored in the next chapter.

Nonetheless, the small sample size was a clear limitation. Further research is required with a larger sample size. In addition, the use of healthy students who were allowed to maintain any training programme is potentially problematic. Although participants were asked not to change their lifestyle, they were not asked to suspend any ongoing training in which they were engaged. It is possible that the changes pre to post such as the increase of weight, were a result of any external training programme and not of the stair climbing intervention. Therefore, a sample that was primarily sedentary and not in any sport training programme was required. This fact was an important criterion for the future study. As stated above, as some participants have put on weight, it is obvious that the body weight was increased due to an increase in lean body mass and not only because of stair climbing. This is an additional limitation of this pilot study. Nevertheless, the purpose of this pilot study was not only to obtain good results in health; but to explore the willingness of people to use this kind of activity at home and to measure some potential outcomes. Definitely future studies need to be more careful in terms of the selection of individuals as well as instructions prior to the experiment, to avoid any form of exercise during the research protocol. It would be more appropriate to only choose participants who lead a sedentary life. As is stated above, by conducting this preliminary analysis before committing to a full study, we enrich our knowledge regarding what to avoid in the future to minimize the faults that occurred in this pilot study.

To conclude, this simple form of exercise at home can lead to encouraging effects on people's health. Stair climbing does not require a specific time of day to be done, clothing or money. Participants just need motivation and some time when at home to improve health. This pilot study tested the practicality of stair climbing at home. All participants were able to progressively increase their start climbing with no reported problem. It is a limitation of this pilot study that follow-up interviews did not assess a major aspect of feasibility, namely the acceptability of the stair climbing at home and how they scheduled the increased activity within their daily life.

2.4.1. Calculations to be made for the subsequent study

Before the intervention programme, habitual stair climbing speed will be measured in subjects as they climb a single flight of 10 steps at moderate intensity. This rhythm will be considered as the terminus pace of training. The study will be separated into three parts. In Boreham *et al.,* (2005) and Boreham, Wallace and Nevill, (2000) participants climbed on a staircase in a public access building. The staircase consisted of 199 steps, with a total vertical displacement of 32.8m. The following estimations to match this vertical displacement do not include the descending of stairs that would be required within the home.

2.4.1.1. GROUP 1. Home-based stair climbing

Stair climbers will be asked to undergo an 8-week stair climbing programme. In a typical two- storey house in Cyprus, there are 20 steps and each step has 17cm riser height. According to Boreham's *et al.,* (2005) protocol, the number of stairs and flights will be determined. These estimations will be done individually according to each participant's riser height and number of steps in their house. This physical activity is to be completed five times.week^{-1} and the minimum resting time between bouts would be set at 10 minutes to allow recovery. In this protocol, unlike Boreham *et al.,* (2005), participants were not instructed to spread the stair bouts throughout the day though they could have chosen to do so. If at a participant's house there are 20 steps, 17cm for each riser height, then they would climb based on the following calculations:

3280cm/17cm = 193 stairs => 193 stairs/20 stairs= 9.65 flights of stairs.

This means that the participant needs to ascend/descend their stairs at home 9.65 times (≈ 10 flights for each bout of physical activity). For the first two weeks, participants will undergo two bouts of flights comprised of 193 stairs for each bout, with an additional increment of one bout of physical activity for every two weeks up to five bouts of physical activity in weeks seven and eight. Accordingly, an 8-week stair climbing programme will take place, progressing from two bouts of ascents.day^{-1} in weeks one and two to five ascents.day^{-1} during the weeks seven and eight. Based on estimated speed of climbing, this programme will last approximately 10 min.day^{-1} for the first two weeks (5+5), 15 minutes for weeks three and four (5+5+5), 20 minutes for weeks five and six (5+5+5+5), and 25 minutes for the last two weeks (5+5+5+5+5). Each bout occupies about five minutes of continuous climbing and descending and each participant will be free to choose whenever they want to undergo the physical activity throughout the day. Each participant will be allowed to ascend and descend the stairs in their own rhythm pace.

2.4.1.2. GROUP 2. Gym-based climbing on a stair machine

The intervention for the laboratory group will be conducted in the main building of Body-Care Maria Ioannou Gym, Limassol Cyprus to explore whether home and laboratory based stair climbing interventions will have equivalent training effects. Participants will be asked to complete the number of continuous climbs on a stair master machine (LEEKON Stair Machine intergraded gym trainer-fitness stepper LK-7000), according to the vertical displacement of Boreham *et al.,* (2005). The riser height of the each of the stair machine's steps is 23cm. Special instructions for the proper stepping technique will be initially shown by the researcher before the beginning of the stair climbing intervention: correct positioning of the body, lower limbs and stepping rate; and how to use the assistance of the side rail when disembarking the stair machine. Then, a trial will be performed by the subjects until a correct technique is obtained. The proper technique will be shown by the researcher on the beginning of each week to each participant's programme to confirm the correct performance. The protocol will be implemented by dividing the vertical displacement (cm) by the height of the stairs on the stair machine (3280/23=142.6 ≈ 143 steps). During the first two weeks, participants should have undergone two bouts of stair climbing (143+143) stairs, by adding an extra bout of stair climbing every two weeks accordingly. The protocol will last eight weeks where the final target is to be able to complete five bouts of stair climbing (143+143+143+143+143). This protocol will take place five times.week^{-1}, and the minimum resting time between bouts will be set at 10 minutes as it is for the home-based group.

The stepping protocol will be given in a table to facilitate the correct amount of steps for the participant (Table 2.3).

Table 2.3. Stepping protocol

Week	*Number of bouts*	*Number of steps*	*Total number of steps*
1-2	2	143+143	286
3-4	3	143+143+143	429
5-6	4	143+143+143+143	572
7-8	5	143+143+143+143+143	715

The protocol lasts approximately six min.day-1 for each ascent for the first two weeks (3+3), nine minutes for weeks three and four (3+3+3), 12 minutes for weeks five and six (3+3+3+3), and 16 minutes for the last two weeks (3+3+3+3+3). Each session lasts for three minutes and each participant is free to chose whenever they want to undergo the climbing spread throughout the day. This physical activity is not too strenuous as each participant was allowed to ascend and descend the stairs in a rhythm and pace of 50-60 steps.min-^{1} according to the screen on the stair trainer. This gym-based protocol will be checked intermittently by the researcher and it will be adapted according to each participants endurance to keep going without any interruption during each bout of stair climbing.

For the control group, participants will be asked not to change their diet and to continue their normal daily activities. After the 8-week intervention programme, health tests will be repeated for all the subjects.

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CHAPTER 3 - USING STAIRS AT HOME TO REDUCE CARDIOVASCULAR DISEASE RISK IN SEDENTARY WOMEN; A CONTROLLED STUDY

3.1. Abstract

Title: Using stairs at home to reduce cardiovascular disease risk in sedentary women; a controlled study.

Background: Stair climbing is a lifestyle activity that does not require specific equipment. This study compared the effects of home-based and gym-based stair climbing on cardio-vascular disease risk factors in sedentary women.

Design: Effects of home-based or gym-based stair climbing were compared with healthy weight controls.

Objectives: To explore the training effects of an 8-week stair climbing intervention on cardio-respiratory fitness, resting heart rate, body composition and lipoprotein profiles.

Methods: Sedentary women, 24 healthy weight and 26 overweight, were randomly assigned to gym-based and home-based stair climbing for five days.week^{-1} over an 8-week period. Participants progressed from two ascents.day^{-1} in weeks one and two to five ascents.day^{-1} in weeks seven and eight. Calculations based on the number and height of each participant's stairs at home matched the vertical displacement occurring with the gym-based stair climber. Repeated-measures analyses of variance tested for differences by weight status and location.

Findings: Stair climbing improved body composition, cardio-respiratory fitness and serum lipid profiles. Effects were similar for gym-based and home-based interventions.

Conclusions: This study reveals that home-based and gym-based stair climbing can confer similar cardiovascular health benefits in sedentary women. Home-based stair climbing may offer a cost-effective intervention for cardio-vascular risk to public health.

Keywords: *stair climbing, lipoproteins, cardio-respiratory fitness, body composition, home-based exercise*

3.2. Introduction

While cardiovascular disease (CVD) is the major cause of death worldwide (Global Burden of Disease 2013; 2015), in the UK cancer has overtaken CVD as the leading cause of death in men whereas in women CVD remains the major cause of mortality (Bhatnagar *et al.,* 2015). Cardiovascular disease is a major cause of functional restriction and death, with costs for England in 2013 estimated at about £6.8 billion, approximately seven percent of the National Health Service (NHS) budget (Bhatnagar *et al.,* 2015). Modifiable risk factors for CVD that can be altered by lifestyle changes include physical activity, and the associated changes in cardio-respiratory fitness, body mass, blood pressure (BP), lipoproteins and blood sugar concentrations (Spencer, Heidecker & Ganz, 2016).

In 2007, 61% of men and 71% of women in England reported that they were less active than the recommended amount to achieve fitness benefits (Health Survey for England 2007; 2008). Objective measures revealed the true level of insufficient activity, 94% of men and 96% of women were insufficiently active. In the US, 34% of men and 42% women reported being less active than required. Objective measures revealed similar levels of insufficient activity to the UK (89% men, 91% women; Tucker, Welk & Beyler, 2011). Increased physical activity is a persistent target to improve population health. Furthermore, vigorous activity has been shown to confer more protection than activity of moderate intensity (Yu *et al.,* 2003; Janssen & Ross, 2012; Laursen *et al.,* 2012).

Stair climbing is a vigorous activity of daily living. At 9.6 metabolic equivalents (METs) when measured in the field, stair climbing requires more energy per minute than jogging (Teh & Aziz, 2002). Observational studies reveal that stair climbing is protective for Coronary heart disease (CHD) and stroke (Paffenbarger *et al.,* 1986; Lee & Paffenbarger, 1998). In the first formal test of the feasibility of increased stair climbing, males who accumulated 25 or more floors of stair climbing daily at work for 12 weeks increased cardio-respiratory fitness [Maximum oxygen uptake ($\dot{V}O_2$Max)] by 10% (Fardy & Ilmarinen, 1975). In a follow-up study, females improved $\dot{V}O_2$Max with additional 13 floors.day^{-1} over 24 weeks (Ilmarinen, *et al.,* 1979), but only the elderly (+4.8%) and less aerobically fit individuals (+6.3%). All subsequent studies confirm improvements in indices of aerobic fitness for inactive participants at baseline (Boreham, Wallace & Nevill, 2000; Boreham, *et al.,* 2005; Kennedy *et al.,* 2007; Meyer, *et al.,* 2010), with an intervention in the elderly improving functional fitness such that reported effort, heart rate and lactate increases during uphill walking (8% slope) were attenuated (Donath, *et al.,* 2014). Less consistent, but encouraging, evidence of improvements in lipoproteins, BP and body fat with increased stair climbing has been reported (Boreham *et al.,* 2000; 2005; Kennedy *et al.,* 2007; Meyer *et al.,* 2010). Current guidelines for physical activity suggest that the accumulation of 10 minute bouts of at least moderate intensity will achieve cardio-respiratory benefits (World Health Organization, 2010). Bouts of stair climbing involving a vertical displacement of 24-33m in these interventions would require about two minutes of continuous activity (Boreham *et al.,* 2000; 2005; Teh & Aziz, 2002; Kennedy *et al.,* 2007). Stair climbing can increase fitness with a lower time commitment than conventional physical activities such as normal walking. These consistent effects of stair climbing interventions are encouraging; cardio-respiratory fitness has protective effects for both premature morbidity and mortality. Low aerobic fitness conferred a relative risk (RR) for all-cause mortality more than three and five times that of high fitness levels in men and women respectively (Blair *et al.,* 1989; 1995). Low fitness is a precursor of CVD (Blair *et al.,* 1996); the magnitude of risk on mortality from low cardio-respiratory fitness (RR = 1.52) was estimated as greater than the relative risks from high BP (RR = 1.30), high cholesterol (RR = 1.34), high blood sugars (RR = 1.24) and being overweight (RR =1.02). A more recent meta-analysis confirms these protective effects for cardio-respiratory fitness on CVD in longitudinal studies (Kodama *et al.,* 2009). Cardio-respiratory fitness is one potential mediator of the health outcomes of physical activity (Lee *et al.,* 2011).

This study tested the effects of an 8-week intervention for increased stair climbing on cardio-respiratory fitness, resting BP, blood lipids and body composition in sedentary females. As in previous UK studies, a progressive increase in the number of daily climbs occurred over the intervention period (Boreham *et al.,* 2000; 2005; Kennedy *et al.,* 2007). In a major departure from previous studies, stair climbing in the gym was compared with equivalent volumes of stair climbing at home. We predicted stair climbing would reduce all measured CVD risk factors with two exceptions; increases in $\dot{V}O_2Max$ and high density lipoprotein (HDL) cholesterol were expected.

3.3. Methods

3.3.1. Study population

Female individuals were recruited from four different companies which involved sedentary office workers. The recruitment process was initially through electronic mail and interviews were arranged for individuals who were interested to participate. Female volunteers completed the short form of the International Physical Activity Questionnaire, (IPAQ) to identify sedentary individuals who met the inclusion criterion of age 18-45 years. Sedentary was defined as participating in no more than 40 minutes of moderate to vigorous physical activity (MVPA) per week and not expecting to begin any type of exercise for the next two months.

Calculations of power for the study were based on the non-significant reductions in triglycerides in the stair climbing group in Boreham *et al.,* (2005). Triglycerides, along with HDL, are two of the components of the five risk factors that define cardiometabolic risk (Alberti *et al.,* 2009). No previous study had demonstrated effects on triglycerides. With α at 0.05 and 80% power a sample size of 42 in the experimental group would be required. As this estimate of change was based on only eight individuals, an inadequate sample to accurately test distributional properties, we erred on the side of caution and recruited 50 individuals.

Initially, 52 females volunteered to participate and were randomly assigned to home-based stair climbing, gym-based stair climbing and control group. Exclusion criteria were history of diabetes, osteoarthritis, CVD or other medical conditions that would impede regular stair climbing, and contraindications on the physical activity readiness questionnaire (PAR-Q). During the first two weeks of the study, two climbers withdrew because of illness whereas one control did not return for the post-test. The final stair intervention group (n = 50) was composed of home-based (13 healthy weight, 13 overweight) and gym-based (11 healthy weight, 13 overweight), with a healthy weight, no-intervention control group recruited (n=10).

Table 3.1 summarises the age, smoking status, body mass index (BMI), estimated $\dot{V}O_2$Max and physical activity from the IPAQ of the three groups.

Table 3.1 Baseline characteristics of participants

Variable	Gym (*SE*) (n = 24)	Home (*SE*) (n = 26)	Controls (*SE*) (n = 10)
Age (years)	31.58 (1.41)	31.76 (1.33)	32.00 (2.75)
Smoking n (%)	8 (30)	12 (46)	5 (50)
BMI	26.33 (1.18)	27.80 (1.11)	20.59 (0.59)
$\dot{V}O_2Max$ (ml.min^{-1}.kg^{-1})	25.67 (0.85)	24.98 (0.86)	25.50 (1.32)
Weekly MVPA[a] (min)	9.38 (2.63)	10.96 (2.04)	52.00 (28.12)

a MVPA = moderate to vigorous physical activity.

The control group had lower BMI and participated in more MVPA than the stair groups (both p <.003). There were no differences between the home and gym-based climbers (all p > 0.36).

Travelling expenses were paid and a report of each participant's results provided as a thank you for participation. Participants were asked not to change their diet or physical activity over the experimental period. Ethical approval was received from the University of Nicosia ethics subcommittee and all participants gave written informed consent.

3.3.2. Protocol and Equipment

The following measurements were completed before the intervention started and repeated at the end of the 8-week intervention period.

3.3.3. Anthropometric characteristics

Body mass and height were assessed using the FitBit Aria Scale with the participants in light indoor clothing without shoes. Half a kilogram was deducted from the measured mass to account for clothing worn. A Harpenden Skinfold Caliper (Harpenden Skinfold Body Assessment Software, Baty International, 2013) was used for skinfold measurements. Measurements of each skinfold were taken twice (triceps, chest, midaxillary, subscapular, suprailiac, abdominal, thigh), with the average of the measures used. Percentage of body fat was calculated by the 7-site skinfold equation according to Jackson & Pollock, (1980).

3.3.4. Blood pressure

Resting heart rate (RHR) and BP (left brachial) were measured twice at a two minute interval between 9:00am-10:00am with an automatic wrist BP monitor (Life source A&D Medical UB-328) after 5 minute of quiet lying in supine position (Meyer *et al.,* 2010). The wrist was positioned at heart level, with an armrest if necessary. The two readings were averaged.

3.3.5. Cardiorespiratory fitness and leg power

For the fitness test, participants had a light breakfast one hour before the test (three whole-wheat crackers + 80g cottage cheese + 10ml honey + 250ml fresh orange juice). To estimate cardio-respiratory fitness, the $\dot{V}O_2$Max proxy from the Multi-Stage Fitness Test (MSFT) which allows simultaneously testing of more than one participant was used (Leger & Lambert, 1982) as used by the Eurofit test guidelines as an estimation of cardiorespiratory endurance. The MSFT, also known as the 'bleep test', involves a 20 metre shuttle run between two points. Each shuttle must be completed before a bleep is played over a loudspeaker. The time between each bleep progressively decreases, requiring participants to increase their pace to reach the point before the next bleep. Eventually, the participant is unable to complete a shuttle run before a bleep at which point the test ends for that participant. The level and bleep reached can be used to estimate $\dot{V}O_2$Max (Leger & Lambert, 1982). The testing was carried out in groups of 3-4 participants. The relationship between MSFT score and $\dot{V}O_2$Max has been found to be independent of sex and age (Armstrong & Duggan, 1990). Rate of perceived exertion (RPE) was recorded at every change of level; participants pointed with their finger at the level of their exertion on a large board displaying the exertion levels (6-20 scale; Borg, 1982). The final RPE level at which a participant could not complete the shuttle run was recorded.

Assessment of leg power used the counter movement jump (CMJ) without arm swing. The time of flight was recorded with a Bosco Ergojump mat (Bosco Ergojump System**,** Byomedic S.C.P., Barcelona, Spain). Participants began from an upright standing position with arms on hips. On a signal, the participant squatted down to the 90 degree leg bend position and immediately jumped as high as possible. Participants were instructed to maintain their body posture and shape during the flight. Participants performed one practice trial and then three attempts with a small rest in between (15 sec). The best score rather than the average was employed. Height jumped in cm as an index of leg power was derived from the equations of Komi and Bosco, (1978), and Bosco, Luhtanen and Komi, (1983).

3.3.6. Blood measurements

Participants consumed a uniform evening meal (100g grilled chicken breast + 50g total low fat yogurt + one cup chopped salad lettuce with cucumber + 8g olive oil + one slice whole wheat bread) followed by a 12 hour fast prior to the blood tests. All data were collected between 08:00 and 10:00. Blood was collected in plain vacutainer tubes and subsequently measured for total cholesterol (TC), HDL-cholesterol, low density lipoprotein (LDL)-cholesterol and triglycerides, whereas glucose measurements employed sodium fluoride tubes to prevent glycolysis. The bloods were processed with standard laboratory methods on a Cobas 400 plus Analyzer (Cobas INTEGRA - ROCHE) in a clinical laboratory subject to external quality control ESEAP, the national External Quality Assessment Scheme for clinical chemistry in Greece and Cyprus. Low density lipoprotein cholesterol was quantified from direct measurement to minimise accumulated errors. Lactic acid was tested with a portable Accutrend Plus System capillary blood tester (Accutrend Plus Coba - ROCHE) immediately after the termination of the 20m MSFT.

3.3.7. Intervention programme

The study set out to replicate the height of climb, 32.8m, used by Boreham *et al.,* (2005) when climbing on a public access staircase. A typical two story house in Cyprus, has 20 steps to reach the next floor, each with a riser height of 17cm. Thus, an individual climbing at home would require 3,280cm ÷ 17 ÷ 20 = 9.6 ascents to climb 32.8m. This was rounded to 10 floors of continuous climbing and descending for a single bout in this house. Equivalent calculations were completed for each building in which home-based stair climbing would occur. Each participant was allowed to choose the pace at which they would ascend and descend the stairs.

The gym-based group climbed on a LEEKON Stair Machine fitness stepper (LK-7000) with a step height of 23cm in the Maria Ioannou Gym, Limassol, Cyprus. Thus, 3,280cm ÷ 23 = 142.6 steps, rounded to 143 steps, was required for a single bout. Each participant was allowed to choose a starting pace between 50-60 steps.min^{-1} for each bout. If they felt comfortable climbing at a faster pace at a later point they could increase it. Participants did not walk down on the machine as the machine is only designed for ascending.

For the 8-week stair climbing intervention, participants started with two bouts of climbing, five days.week^{-1} for the first two weeks. For each subsequent 2-week period, a further daily bout of climbing was added so that they progressed from two bouts.day^{-1} to five bouts.day^{-1} in weeks seven and eight of the intervention period. Special instructions for the proper stepping technique were initially shown to each participant before the commencement of the intervention; to confirm the correct performance. For each subsequent 2-week period participants were reminded to increase their number of daily bouts at each transition by phone. This gym-based protocol was checked intermittently by the researcher over the 8-week period. Both home-based and gym-based participants were instructed to rest for a minimum of 10 minutes between each bout. The control group was instructed not to change their diet and to continue their normal daily activities for an 8-week period.

3.3.8. Statistics

Analyses employed a two-stage process *a priori*. First, repeated measures analyses of variance with the within subject factor of pre vs. post compared the combined intervention groups with the controls. Second, repeated measures analyses of variance in the intervention groups alone with the between subject factors of location (gym vs. home) and weight status (healthy weight vs. overweight) tested for the predicted effects pre vs. post and for any differences between the subgroups. Significant effects were followed up with paired *t*-tests where required. Results are presented as mean ± *SE* and two-tailed probabilities reported for all statistical testing.

3.4. Results

Table 3.2 summarises the means (*SE*) pre vs. post for the control group and the healthy weight and overweight groups. In addition, the table summarises the results of statistical testing. The first column (Cnt:Exp x pre:post) tests for the predicted interaction of improvement following intervention in the stair groups relative to controls. As two-tailed probabilities are employed throughout, $p \leq .10$ represents the predicted interactions. The second column summarises the comparison of pre with post values for the stair groups alone, i.e. tests for effects of stair climbing on each variable. The third column (weight status) summarises any overall differences by weight, with the final column summarising any differences between the weight groups in the effects of the intervention.

Table 3.2 Means (SE) for the study variables pre- and post- intervention for the control, healthy weight and overweight groups, with a summary of statistical testing.

Variable	Control (n=10) Pre (*SE*)	Control (n=10) Post (*SE*)	Healthy weight (n=24) Pre (*SE*)	Healthy weight (n=24) Post (*SE*)	Overweight (n=26) Pre (*SE*)	Overweight (n=26) Post (*SE*)	Cnt:Exp[a] x Pre:post $F_{1,58}$, *prob.*	Stair group Pre:post $F_{1,46}$, *prob.*	Weight status $F_{1,46}$, *prob.*	Weight x Pre:post $F_{1,46}$, *prob.*
Weight (kg)	52.87 (1.45)	52.91 (1.49)	58.72 (2.07)	57.54 (2.03)	84.19 (1.37)	83.38 (1.36)	5.41, $p = 0.02$	25.89, $p < 0.001$	126.01, $p < 0.001$	0.93, $p = 0.34$
Body fat (%)	22.52 (1.15)	21.79 (1.14)	25.66 (1.57)	22.15 (1.38)	31.22 (0.58)	30.7 (0.79)	2.58, $p = 0.11$	39.34, $p < 0.001$	22.19, $p < 0.001$	12.72, $p = 0.001$
Systolic blood pressure (mmHg)	115.60 (2.16)	114.00 (2.42)	114.41 (2.02)	112.00 (2.02)	127.00 (1.49)	125.04 (1.45)	0.05, $p = 0.82$	4.25, $p = 0.05$	27.77, $p < 0.001$	0.07 $p = 0.79$
Diastolic blood pressure (mmHg)	79.00 (1.85)	72.60 (2.48)	73.87 (1.44)	71.87 (1.99)	78.42 (1.16)	78.69 (1.16)	8.15, $p = 0.006$	1.25, $p = 0.27$	8.36, $p = 0.006$	2.14 $p = 0.15$
Resting heart rate (bpm)	82.90 (3.58)	81.60 (2.33)	85.87 (2.59)	82.87 (2.06)	84.31 (1.97)	83.65 (1.60)	0.02, $p = 0.90$	1.78 $p = 0.19$	0.03, $p = 0.86$	0.79 $p = 0.38$
$\dot{V}O_2$Max ($ml.min^{-1}.kg^{-1}$)	25.50 (1.32)	26.03 (1.52)	26.82 (1.05)	28.95 (1.19)	23.94 (0.52)	25.10 (0.57)	4.91, $p = 0.03$	64.97 $p < 0.001$	7.71, $p = 0.008$	5.68 $p = 0.02$
Lactate ($mmol.L^{-1}$)	10.52 (0.71)	9.76 (0.90)	11.68 (1.01)	8.02 (0.73)	12.14 (0.82)	10.51 (0.75)	2.87, $p = 0.10$	31.63 $p < 0.001$	1.90, $p = 0.17$	4.45 $p = 0.04$

Rate of perceived exertion	16.80 (0.80)	17.00 (0.82)	16.71 (0.75)	16.79 (0.53)	16.58 (0.67)	17.00 (0.64)	0.01, $p = 0.94$	0.49 $p = 0.49$	0.02, $p = 0.89$	0.23 $p = 0.63$
Counter movement jump height (cm)	20.73 (1.52)	20.40 (1.60)	19.71 (1.38)	21.14 (1.51)	17.76 (1.23)	18.81 (1.36)	2.33, $p = 0.13$	8.19, $p = 0.006$	0.92, $p = 0.34$	0.01, $p = 0.91$
HDL cholesterol (mmol.L^{-1})	1.58 (0.06)	1.64 (0.06)	1.52 (0.08)	1.70 (0.08)	1.28 (0.06)	1.36 (0.06)	2.80, $p = 0.10$	69.43, $p < 0.001$	8.50 $p = 0.005$	9.85 $p = 0.003$
LDL cholesterol (mmol.L^{-1})	2.74 (0.26)	2.88 (0.22)	2.90 (0.21)	2.64 (01.8)	3.86 (0.20)	3.71 (0.19)	7.21, $p = 0.009$	14.02, $p = 0.001$	14.02, $p = 0.001$	1.07 $p = 0.31$
Non-HDL cholesterol (mmol.L^{-1})	2.93 (0.24)	2.95 (0.24)	3.93 (0.22)	2.67 (0.20)	3.90 (0.21)	3.77 (0.20)	3.70 $p = 0.06$	18.71, $p <0.001$	12.14, $p = 0.001$	4.45, p = 0.04
Triglycerides (mmol.L^{-1})	0.93 (0.09)	0.97 (0.15)	0.93 (0.10)	0.79 (0.07)	1.77 (0.70)	1.48 (0.06)	10.87 $p = 0.002$	54.07, $p < 0.001$	63.19, $p < 0.001$	6.92 $p = 0.01$
Glucose (mmol.L^{-1})	5.00 (0.12)	5.03 (0.07)	5.03 (0.08)	4.92 (0.10)	5.05 (0.08)	5.03 (0.09)	0.52 $p = 0.48$	1.12 $p = 0.30$	0.14 $p = 0.72$	0.44 $p = 0.51$

a: cnt = control; exp = experimental

As can be seen from the first summary column of statistical testing in the table, relative to controls, stair climbing improved one index of body composition (weight), both indices of cardio-respiratory fitness ($\dot{V}O_2$Max, lactate) and all measured lipoproteins (HDL, LDL, Non-HDL cholesterol, triglycerides), with statistically significant improvements in the stair group shown in the next column, all $p < .001$. In addition, percentage body fat and systolic blood pressure (SBP) were reduced after the intervention in the stair group whereas leg power (CMJ) increased. For diastolic blood pressure (DBP), however, the differences between the controls and intervention group pre vs. post resulted from a reduction in the control group ($p = 0.01$). There was no evidence of beneficial effects of stair climbing on RHR or fasting blood glucose.

Concerning significant differences by weight status, the overweight group weighed more, had more body fat, higher systolic and diastolic blood pressures, lower cardio-respiratory fitness, lower HDL cholesterol, higher LDL and non-HDL cholesterol and triglycerides. Further, the intervention had greater magnitude effects in the healthy weight group than in the overweight participants for percentage body fat, $\dot{V}O_2$Max, lactate, HDL and non-HDL cholesterol, with the converse true for triglycerides. Nonetheless, both groups improved significantly for these variables (all $p < 0.05$). In contrast, there were no significant differences by weight status for the effects of stair climbing on improvements in weight, leg power or LDL cholesterol. It should be noted that the absence of any differences in RPE at the end of MSFT demonstrates that the groups reached a similar level of exertion during fitness testing.

Table 3.3 summarises the means (*SE*) pre vs. post for the gym-based and home-based intervention groups.

Table 3.3 Means (*SE*) for the study variables pre and post for the gym and home-based groups, with a summary of statistical testing.

Variable	Gym (n=24)		Home (n=26)		Group $F_{1,46}$, *prob.*	Group x Pre:post $F_{1,46}$, *prob.*
	Pre (*SE*)	Post (*SE*)	Pre (*SE*)	Post (*SE*)		
Weight (kg)	68.31 (3.03)	67.17 (3.03)	74.35 (3.11)	73.49 (3.14)	7.17, p = 0.01	0.56, p = 0.46
Body fat (%)	26.92 (1.18)	24.82 (1.28)	29.79 (1.30)	27.46 (1.32)	3.44, p = 0.07	0.11, p = 0.74
Systolic blood pressure (mmHg)	121.70 (2.28)	118.87 (2.64)	120.26 (2.06)	118.69 (2.04)	0.02, p = 0.89	0.39 p = 0.54
Diastolic blood pressure (mmHg)	77.04 (1.21)	76.41 (1.52)	75.50 (1.48)	74.50 (1.89)	0.72, p = 0.40	0.02 p = 0.88
Resting heart rate (bpm)	86.00 (1.57)	82.54 (1.24)	84.19 (2.73)	83.96 (2.19)	0.01, p = 0.92	1.39 p = 0.25
$\dot{V}O_2$Max ($ml.min^{-1}.kg^{-1}$)	25.67 (0.85)	27.27 (0.99)	24.98 (0.86)	26.63 (0.98)	0.45, p = 0.51	0.00 p = 1.00
Lactate ($mmol.L^{-1}$)	11.20 (0.69)	8.89 (0.69)	12.58 (1.04)	9.70 (0.84)	1.08, p = 0.30	0.32 p = 0.57
Rate of perceived exertion	15.62 (0.81)	16.91 (0.74)	17.57 (0.54)	17.80 (0.31)	5.41, p = 0.03	0.00 p = 0.96
Counter movement jump height (cm)	19.93 (1.54)	21.84 (1.67)	17.56 (1.07)	18.16 (1.12)	0.92 p = 0.34	0.01 p = 0.91
HDL cholesterol ($mmol.L^{-1}$)	1.41 (0.06)	1.51 (0.07)	1.38 (0.08)	1.54 (0.08)	0.01 p = 0.93	2.65 p = 0.11
LDL cholesterol ($mmol.L^{-1}$)	3.31 (0.19)	3.10 (0.27)	3.47 (0.24)	3.28 (0.22)	0.64, p = 0.43	0.03 p = 0.86
Non-HDL cholesterol ($mmol.L^{-1}$)	3.32 (0.19)	3.09 (0.21)	3.62 (0.25)	3.38 (0.23)	1.41, p = 0.24	0.00, p = 0.96
Triglycerides ($mmol.L^{-1}$)	1.30 (0.13)	1.14 (0.11)	1.42 (0.10)	1.15 (0.07)	1.31, p = 0.26	4.51 p = 0.04
Glucose ($mmol.L^{-1}$)	5.01 (0.09)	5.11 (0.09)	5.06 (0.05)	4.85 (0.08)	0.81 p = 0.37	8.61 p = 0.005

The first column of statistical testing summarises the results of comparisons between the groups overall whereas the second tests for differential effects of gym and home-based climbing. As can be seen, the home-based group weighed more overall and reported higher rates of perceived exertion at the end of the MSFT. Only two variables provided any evidence of differential effects of intervention location. Triglycerides were reduced more in the home-based group though both groups improved post intervention (both $p < 0.001$). The differential effect for glucose resulted from a contrast between a significant reduction in the home-based group ($p = .01$) and a non-significant increase in the gym-based participants ($p = .15$).

3.5. Discussion

Compared to controls, stair climbing improved body composition (weight), cardio-respiratory fitness ($\dot{V}O_2$Max, lactate) and lipoproteins (HDL, LDL, Non-HDL cholesterol, triglycerides). These differences provide strong evidence of efficacy. In addition, improvements at the end of the intervention occurred for percentage body fat and leg power in stair climbers. Stair climbing did not improve DBP, RHR or fasting blood glucose. For the latter result, fasting blood glucose was in the healthy range for both weight groups (healthy weight $M = 5.03 \pm 0.08$ mmol.L^{-1}; overweight $M = 5.05 \pm 0.08$ mmol.L^{-1}). Further reductions may be unlikely to result from an 8-week intervention in individuals with a healthy profile at baseline (Tsukui *et al.,* 2000; Mensink *et al.,* 2003).

For effects on body composition, these controlled comparisons confirm the results for an uncontrolled report of reductions in weight and body fat (Meyer *et al.,* 2010). Improvements in cardio-respiratory fitness are consistent with all previous tests in the field (Boreham *et al.,* 2000; 2005; Kennedy *et al.,* 2007; Meyer *et al.,* 2010). Indeed, relatively low volumes of increased stair climbing can improve cardio-respiratory fitness; accumulations of 24 and 21 floors daily improved fitness in the studies of Kennedy *et al.,* (2007) and Meyer *et al.,* (2010) respectively. For lipoproteins, the comprehensive effects here surpass all previous studies.

Concerning differential effects by weight status, the overweight were at greater CVD risk based on body composition, BP, cardio-respiratory fitness and lipoproteins, consistent with their weight status. Despite this elevated risk, greater effects of intervention in the healthy weight group occurred for one measure of body composition (body fat), cardio-respiratory fitness ($\dot{V}O_2Max$, lactate) and cholesterol (HDL, Non-HDL) whereas there were greater effects in the overweight group for triglycerides. Although significant improvements occurred in both weight groups, greater magnitude changes in the less healthy would have been possible and were expected.

For differences in cardio-respiratory fitness estimated with the MSFT, the overweight would be at a disadvantage as the repeated changes in direction required for shuttle running would disproportionately affect those who have more body mass to decelerate and accelerate when they change direction. Had $\dot{V}O_2Max$ been estimated from cycle ergometry rather than shuttle running, a different result might have been obtained. Nonetheless, healthy weight and overweight participants reported equivalent rates of exertion on the Borg scale at the end of the shuttle run, suggesting that they were working to the same level during the test. Despite this, lactate production was reduced more in the healthy weight participants than the overweight suggesting that cardio-respiratory fitness had improved more in the healthy weight group. Speed of climbing will influence the cardio-respiratory load; faster climbing will have greater effects on cardio-respiratory fitness consistent with the greater rate of work required. One possible explanation for a greater effect on cardio-respiratory fitness, and other measured variables, could be that the healthy weight group climbed faster during their bouts than the overweight; more intense physical activity is typically associated with greater benefits (Yu *et al.,* 2003; Janssen & Ross, 2012; Laursen *et al.,* 2012). Alternatively, the healthy weight group may have completed more of the intervention protocol. Unlike Boreham and co-workers, participants here did not keep a log of their climbing bouts that would address this question.

These stair climbing interventions improved all measured lipoproteins. In contrast, Boreham *et al.,* (2000) with six ascents.day^{-1} when using young healthy volunteers (~ 20 years) improved only HDL, Boreham *et al.,* (2005) with five ascents.day^{-1} reduced LDL but had no effects on HDL or triglycerides, whereas Kennedy *et al.,* (2007) with only three ascents.day^{-1}, did not change any lipoproteins. The target of five ascents in the final two weeks here represented a similar volume of stair climbing to Boreham *et al.,* (2000) and Boreham *et al.,* (2005) that affected some lipoproteins but more than the three daily ascents in Kennedy *et al.,* (2007) that had no effect. The comprehensive effects on all measured lipoproteins in the present study may reflect the greater statistical power available with 50 participants to detect differences relative to the smaller sample sizes with comparable volumes of climbing of Boreham and co-workers (*n* = 12; *n* = 8).

None of the previous controlled investigations reported changes in body composition as a result of stair climbing (Boreham *et al.,* 2000; 2005; Kennedy *et al.,* 2007); only the uncontrolled study of Meyer *et al.,* (2010) reported improvements. The strong evidence here for improvements for body weight, as well as weaker evidence for changes in body fat, is encouraging, particularly as the weight reductions were similar in both healthy weight and overweight samples. Nonetheless, the work done against gravity to climb will have effects on energy expenditure proportional to the mass raised and speed of climbing makes a relatively minimal contribution to energetic cost. If both weight groups had completed equivalent amounts of the specified protocol, greater reduction in weight might have been expected for the overweight group. The absence of differential effects by weight status would be consistent with a lower total volume of climbing in the overweight group.

For resting cardiovascular variables, the picture was mixed. Weak evidence for effects of climbing on SBP contrasted with a paradoxical reduction in DBP for the control group and no effects on RHR. The safest conclusion is that the 8-week stair climbing interventions in this study did not change BP measured at the wrist whereas the uncontrolled study with upper arm measures by Meyer *et al.,* (2010) was more positive as diastolic blood pressure was significantly improved.

Overall, it is clear that the present study revealed similar changes after home and gym-based stair climbing interventions. Where there were differential effects on triglycerides and glucose, they favoured home-based climbing. Put another way, home-based climbing was at least as effective as the gym-based alternative for 13 different variables, nine of which clearly improved post-intervention. The benefits of physical activity are well documented. What is novel here is that individuals climbing in their own home reduced CVD risk. Kodama and colleagues estimated that a one metabolic equivalent (MET) increase in cardio-respiratory fitness would produce a 15% reduction in CVD risk (Kodama *et al.,* 2009). Stair climbing at home here improved fitness by about half a MET (+0.47, 95% confidence interval = +0.30, +0.65) in a relatively low-fit group for their age (overall $\dot{V}O_2$Max

= 25.3 ml.min^{-1}.kg^{-1} ± 0.6). As Blair and colleagues have pointed out, greater benefits occur for improvements in less fit individuals (Blair, Cheng & Holder, 2001; Lee *et al.,* 2011).

There are few logistical barriers to stair climbing at home, unlike gym-based exercise. It is a simple lifestyle activity that can be accumulated in short bouts. Based on the climbing times in Teh & Aziz, (2002), and unpublished data (Eves, Kerr & Carroll, unpublished), the combined ascent and descent would require approximately four and half minutes, about the length of a commercial break in a television programme. Indeed, a recent laboratory based study of sedentary females that supervised bouts of climbing and descending equivalent to about five floors improved cardio-respiratory fitness at a lower temporal cost, about two minutes of activity each day (Allison *et al.,* 2017). As noted above, relative low volumes of increased stair climbing can improve cardio-respiratory fitness (Kennedy *et al.,* 2007; Meyer *et al.,* 2010). Further, the speed of climbing at 0.62 m.s^{-1} in Allison and colleagues study was considerably faster than typically chosen. Females in Teh & Aziz (2002) climbed at 0.23 m.s^{-1} whereas, in unpublished data, a younger female sample with four floor ascent climbed at 0.34 m.s^{-1} (Eves, Kerr & White, unpublished). If the rapid rate of climbing in Allison and colleagues research is suitable for the general population, reduced CVD risk could be achieved at less temporal cost than here. Stair climbing does not require equipment or sporting ability and is non-competitive. Most of the population can climb stairs because they already do so as part of daily life. Belief that one can perform the behaviour, called self-efficacy, is rarely a barrier to stair climbing as it can be for formal sport or jogging (Trost *et al.,* 2002). Home-based stair climbing may offer a uniquely, cost-effective approach to CVD risk reduction for public health.

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CHAPTER 4
AN EXPLORATORY STUDY OF POTENTIAL PREDICTORS OF HOME-BASED STAIR CLIMBING IN AN OLDER POPULATION

4.1. Abstract

Title: An exploratory study of potential predictors of home-based stair climbing in an older population.

Background: Ageing is unavoidable for any biological organism and deterioration due to ageing can increase health risk, particularly for cardio-vascular disease (CVD). Increased physical activity can help mitigate this increase in risk. Stair climbing has a range of benefits on physiological outcomes relevant to CVD risk.

Objectives: This study tested potential psychological factors that might influence the willingness of an older population to increase stair climbing at home. Both positive and negative specific outcomes of stair climbing, and fear of falling were tested as potential determinants of willingness to climb in an older population.

Methods: A sample of 281 participants (113 men, 168 women) at or above 45 years old, average age 69.2 ± 0.6 years, completed a short questionnaire. Participants reported the number of floors that they were willing to climb continuously at home. Positive and negative attitudes about regular stair climbing and fear of falling on stairs, as well as in general, were assessed. Participants responded to a series of questions on 6-point scales by circling the appropriate descriptor for agreement and disagreement with the statement posed for each question. Analyses employed hierarchical multiple linear regressions in which the potential demographic predictor variables of sex, age and body mass index (BMI) on the first step were supplemented by psychological variables on subsequent steps.

Findings: Positive and negative attitudes towards climbing stairs regularly were associated with increases and decreases respectively in the willingness to climb stairs at home. When fear of falling on stairs, and falling while walking in general, were included in the analyses, there was no contribution of negative attitudes. Fear of falling on stairs was the major predictor of willingness to climb. Male and younger participants were willing to climb continuously more than their comparison groups.

Conclusions: Positive attitudes to the benefits of stair climbing and fear of falling were the major predictors of willingness to climb stairs at home.

Keywords: *stair climbing, home, ageing, attitudes, fear of falling, cardiovascular disease*

4.2. Introduction

For the first time in history, most people can expect to live to their 60s and beyond (World Economic and Social Survey, 2007). In middle and low-income countries, the increase in life expectancy reflects reduced mortality associated with childbirth and childhood, coupled with reduced effects of infectious diseases (Bloom, 2011). In high-income countries, however, increased life expectancy is mainly due to the decrease in mortality among the elderly (Christensen *et al.,* 2009). For the US, male and female residents aged 65 can now expect to live on average until 84 and 87 respectively (Orkaby *et al.,* 2018). As a result of these demographic changes, in approximately 10-15 years, 20% of the US population will be aged 65 or older (North & Sinclair, 2012). In the UK, adults aged over 65 years increased by 1.5 million from 1983 to 2008, with a concomitant increase of 700,000 for those over 85 years (Office for National Statistics 2009). Nonetheless, ageing is unavoidable for any biological organism and, unfortunately, the natural deterioration due to ageing predisposes people to multiple set of conditions that are related to poor health. As a result, increases in longevity may not be accompanied by well-being and good health.

Conditions such as cardiovascular diseases (CVDs) have a direct impact on health with an increased prevalence with increasing age (Alzaid, Patel, & Preedy, 2014). Hence, ageing is one of the dominant predictors of CVD risk (Benjamin *et al.,* 2017). Risk factors for the Metabolic syndrome (MetS) including abdominal obesity, high fasting glucose, hyperlipidemia and hypertension are linked to the ageing process, as well as insulin resistance. This cluster of symptoms increases the risk of CVD and type 2 diabetes (Nichols *et al.,* 2017). Nonetheless, in the elderly, changing lifestyle by adding exercise that is associated with weight loss can improve insulin resistance and other cardiometabolic risk factors, especially in obese adults over 65 years of age (Bouchonville *et al.,* 2014). Thus, changes in physical activity can mitigate increased disease risk and may also improve self-confidence of the elderly to maintain their physical activity.

In the only national representative sample assessing cardio-respiratory fitness in the UK, increasing age was associated with reduced fitness and leg strength (Allied Dunbar National Fitness Survey, 1992). Longitudinal studies confirm a progressive loss of leg strength as participants get older, with yearly declines (3.1% for men and 2.6% women) typically revealing large effect sizes, i.e. Cohen's d>0.8 (Koster *et al.,* 2011). Loss of leg strength, or more correctly its functional manifestation as leg power, can contribute to limitations in everyday living. For example, leg power has been related to walking speed, timed rising from a chair and rate of stair climbing in the elderly, all measures that can indicate functional limitations in an ageing population (Bean *et al.,* 2002). Navigating the built environment such as going to the shops or visiting a friend requires leg power, as well as balance and aerobic endurance, all of which can decline with increasing age (Gardner *et al.,* 2001). As a result, loss of leg strength is associated with reduced mobility (Hicks *et al.,* 2011), reduced cardio-respiratory fitness that allows prolonged physical activity (Oliveira *et al.,* 2009) and increased rates of falls (Whipple, Wolfson & Amerman, 1987; Pijnappels *et al.,* 2008).

As was reported in Chapter 3, experimental increases in the volume of stair climbing resulted in improvements in body composition and cardio-respiratory fitness, both factors that can decline with increasing age. In addition, improved lipoprotein profiles resulted which would reduce MetS risk and, hence, also the risk of CVD. Concerning an elderly population, the evidence of increased leg power from the counter movement jump (CMJ) was particularly encouraging, maintenance of leg power being protective against a decline in functional activity. Thus, stair climbing can offer considerable benefits for an ageing population. Importantly, these improvements in health markers occurred independent of location; home-based stair climbing was as effective as a gym-based protocol. This exploratory study set out to assess the potential of increased stair climbing at home as a physical activity for an older population.

Home-based exercise programmes have been developed for strength, balance and physical activity endurance training in the elderly (Gardner *et al.,* 2001). These programmes involve relatively simple activities that can be practiced at home. For example, individuals may strengthen the leg extensors in a seated position by raising weights on the ankles, complete knee bends, adopt different stances such as standing on the toes or back on the heels. In addition, the participants can practice walking on the heels or the toes, as well as backward and sideways walking (Gardner *et al.,* 2001). These home-based exercise programmes have been effective in reducing the number of falls and falls related injuries by 35% (Robertson *et al.,* 2002). Although many home-based protocols encourage participants to use stairs rather than lifts or escalators (Gardner *et al.,* 2001), stair use has not been formally included as a potential home-based exercise to date. Raising one's body mass against gravity is a metabolically costly behaviour, requiring 9.6 times the expenditure of the resting state in the field (Teh & Aziz, 2002). While stair climbing has the same ground reaction forces as walking on the level (Spanjaard *et al.,* 2007; 2008; 2009; Reeves *et al.,* 2008), ground reaction forces are three times greater for descent than ascent because the centre of mass falls further onto the leading leg placed on the step below. As a result, repeated climbing of stairs may represent a natural strength training exercise for the legs.

From the above, it is clear that regular stair climbing has the potential to offer several health benefits for an the elderly population. However, it is less clear whether the willingness of stair climbing in the elderly is determined by attitudes to regular stair climbing.

The present study tested potential psychological factors that might influence the willingness of an older population to increase stair climbing at home. Positive and negative specific outcomes of a behaviour are the major determinants of attitudes towards the behaviour (Ajzen, 1985; 1987; 1988; 1991; Eves, Hoppé, & McLaren, 2003; Eves & Hoppé, 2009). Within the most commonly used model of health behaviour, (Ajzen's Theory of Planned Behaviour), attitudes are a major determinant of intention to perform the behaviour and subsequent enactment of the behaviour in longitudinal studies (McEachan *et al.,* 2011). The latter used commonly reported outcomes of stair climbing as measures of attitude towards the behaviour taken from previous focus group work (Thomas *et al.,* 2015, unpublished data). Attitudes represent the motivational beliefs that can be targeted by interventions in any attempt to increase a behaviour. Potential benefits of stair climbing, i.e. reduces heart attacks, may function as motivators whereas negative outcomes, i.e. hurts the knees, may function as potential barriers. As the aim was to explore the potential of home-based stair climbing for an older population, one further barrier was assessed, that of fear of falling.

Falls in the elderly are a major issue with regards to morbidity, mortality and cost for the health care system (World Health Organization, 2007a; 2007b; 2015). Research has shown that 28-35% above 65 years of age, experience a fall at least once a year, while for people above 75, the percentage increases to 32-42%. From all these cases, 20% suffer a hip fracture as a result of an unintentional injury (World Health Organization, 2007). Fear of falling increases with ageing and frailty level. Whereas about 5% of elderly people with hip fractures die while hospitalized, the overall mortality of the elders in the 12 months after a hip fracture (caused by a fall) ranges from 18 to 33% (Gagnon & Flint, 2003; Rubenstein, unpublished data).

An important point here is that the results of falling are not limited to physical injury, but influence psychological wellbeing as well. In most cases, falling results in a loss of self-confidence and fear of another fall, therefore limiting the faller's activities and social contacts (Potoupnis, 2007). Any subsequent reduction in physical activity may be accompanied by a reduction of muscle strength in both men and women. These effects could be exacerbated by any associated increases in the percentage of body mass and loss of mobility, flexibility and cardio-respiratory fitness.

The danger of falling is least among healthy elders, who nonetheless also tend to avoid activities that involve a high risk of falling, although they do not appear to consciously limit their daily physical activities. (Li *et al.,* 2003). Clearly, fear of falling with increasing age is a major potential barrier to increased stair use. Fear of falling could result in a spiralling restriction in physical activity, loss of confidence in the ability to be active and physiological deconditioning that results from inactivity. The study adapted questions from the Falls Efficacy Scale International (FES-I) to assess this important potential barrier to climbing at home (Yardley *et al.,* 2005; Delbaere *et al.,* 2010).

In summary, this exploratory study tested the utility of measures derived from the Theory of Planned Behaviour, as well as fear of falling, as potential predictors of the willingness to climb stairs at home. Information about willingness to climb stairs at home is a necessary precursor of any attempt to adapt stair climbing at home for an older population.

4.3. Methods

4.3.1. Sample

Power calculations were based on unpublished data for response to the single item question '*regular stair climbing helps weight control*' (Eves *et al.,* 2012). For this exploratory study, we wished to find potential motivators for climbing. To explain 3% of the variance of willingness to climb would require a sample size of 256 at $\alpha = 0.05$ and 80% power. A sample of 291 participants at or above 45 years old were recruited. After participants with missing data were excluded the final sample contained 113 men and 168 women. These individuals were recruited from nursing homes, care homes, doctors, neighbors and elderly family members of the research group who met the age criteria of inclusion. Information was given by visiting those places by the researcher. Individuals who agreed to participate completed the questionnaires at the same time. All of the participants were citizens of the Limassol district, Cyprus. Ethical approval was received from the University of Nicosia ethics subcommittee and all participants gave written informed consent.

4.3.2. Questionnaire

The main topic that we sought to investigate was the willingness to climb continuously, in keeping with the beneficial effects of continuous climbing shown in the previous study (Chapter 3). Participants answered the question '*If you were asked to go up and down the stairs continuously in your home, how many times would you be willing to do this? (Up and* *down is a single journey, so if you would be willing to do this once, insert 1)'*. They inserted the number of times in a blank space.

In addition, participants responded to a series of questions on 6-point scales by circling the appropriate descriptor for their answer to the statement posed for each question from the options of '*strongly disagree*' (coded 1), '*moderately disagree*', '*weakly disagree', 'weakly agree'*, '*moderately agree*' and '*strongly agree*' (coded 6). For outcomes of stair climbing, the stem '*Regular stair climbing*' was followed by the positive outcomes of '*will keep me fit*', '*will reduce my risk of a heart attack*', '*provides daily exercise*' and '*will help control my weight*' and negative outcomes of '*is hard work*', '*would hurt my knees*' and '*makes me out of breath*'. To assess potential effects of barriers to stair usage from fear of falling when walking, four questions from the Falls Efficacy Scale International were employed (Delbaere *et al.,* 2010). The stem '*I am worried about falling when*' was completed by the statements '*going up and down stairs*', '*going to the shops*', '*walking up and down slopes*' and '*walking in a place with crowds*'. These items were described by the originators of the scale as assessing 'more demanding physical activities outside the home' (Yardley *et al.,* 2005, p. 616). Participants answered these questions on the same 6-point scale for disagreement and agreement. In addition, participants self-reported their age, height and weight.

4.3.3. Data reduction

Preliminary inspection of the data for positive and negative outcomes of stair climbing with factor analysis using orthomax rotation revealed two separate factors. Negative reported outcomes of performing stair climbing (hard work, hurt knees, out of breath) loaded on one factor that explained 27.9% of the variance whereas the potential positive outcomes (keep fit, reduce risk of heart attacks, daily exercise, help weight control) loaded on a separate factor explaining 28.0% of the variance. Tests of reliability revealed acceptable reliability for the negative items (Cronbach's alpha = 0.68) but less good reliability for the positive items (Cronbach's alpha = 0.62). Attempts to improve the reliability coefficient for the positive items by serial deletion of each item did not improve the estimate. As this was exploratory work, the averages of the three negative and the four positive items were used for analysis, despite the lower reliability for the positive items. For the four items adapted from the fear of falling scale, reliability was good (Cronbach's alpha = 0.77). Nonetheless, the question about fear of falling when climbing stairs was used as a single item, with the reliability of the remaining three questions about fear of falling when walking in general acceptable (Cronbach's alpha = 0.67).

4.3.4. Statistical analysis

Potential differences between men and women were analyzed with *t*-tests. Preliminary inspection of the data used Pearson's product moment correlation with Bonferroni protected probability levels. Analysis of the willingness to climb used hierarchical multiple linear regressions in which the potential demographic predictor variables of sex, age and BMI on the first step were supplemented by positive and negative attitudes to regular stair climbing on the second step, with fear of falling when using stairs and when walking in general added for the final model.

4.4. Results

Overall, the sample was composed of 113 men and 168 women. Table 4.1 summarises the mean (*SE)* for men and women on the measured variables and tests for differences between the sexes.

Table 4.1 Comparison between men and women for the study variables

Variable	Men (SE) (n= 113)	Women (SE) (n = 168)	t (279)	***Probability***
Age	68.50 (0.91)	69.61 (0.81)	0.89	0.38
BMI	27.13 (0.37)	26.41 (0.34)	1.42	0.16
Floors willing to climb	2.09 (0.13)	1.75 (0.10)	2.06	0.04
Positive attitude	5.25 (0.08)	5.22 (0.08)	0.27	0.79
Negative attitude	4.94 (0.12)	5.27 (0.08)	2.40	0.012
Fear of falling on stairs	3.58 (0.19)	4.57 (0.12)	4.67	<0.001
Fear of falling walking	3.76 (0.14)	4.64 (0.10)	5.23	<0.001

As can be seen from the table, men were willing to climb more floors continuously than women. In addition, men were less worried about falling on the stairs and when walking than women, had a less negative attitude to regular stair climbing and had a greater body mass index (BMI) than women, though the latter effect was not statistically significant. To avoid possible confounding of sex differences in willingness to climb continuously with potential predictors of this willingness, BMI and all the questionnaire data were mean centred within each sex. This mean centring was achieved by subtracting the mean value for each sex from all individual values for that sex subgroup. The net outcome of such a transformation is to retain the individual variation within each sex group yet to equate the overall variance between the sexes.

Concerning the magnitude of the psychological variables, a score of 3.5 would be the mid-point of the 6-point scale. Any score greater than 3.5 represents, on average, agreement with the items. In this sample, on average, both men and women agreed with the positive and negative attitudes. In contrast, on average, women agreed with the worry about falling items whereas men were at the mid-point of the scale.

Table 4.2 contains the overall means for the psychological variables (*SE*) and the correlations between them, including age.

Table 4.2. Mean (*SE*) of the psychological measures and the interrelationships between them.

Variable	Mean (*SE*)	Floors willing to climb	Positive attitude	Negative attitude	Fall on stairs	Fall when walking
Floors willing to climb	1.89 (0.81)					
Positive attitude	5.23 (0.06)	.187*				
Negative attitude	5.14 (0.07)	-.322***	.069			
Fall on stairs	4.17 (0.11)	-.506***	-.084	.524***		
Fall when walking	4.29 (0.09)	-.449***	.014	.547***	.653***	
Age	69.16 (0.61)	-.304***	-.129	.162	.284***	.363***

* = *P* <.05, ** = *P* < .01, *** = *P* < .001

As can be seen from the table, all psychological variables were correlated with the number of floors participants were willing to climb, with stronger correlations for negative attitude to regular stair use and worry about falling than for the positive attitude. The strongest correlations in the table were for negative attitude and worries about falling, suggesting some overlap between these potential barriers to regular climbing. In contrast, positive attitude that represents potential benefits of regular stair use was not significantly correlated with the potential barriers.

Table 4.3 below summarizes the results of the 3-step hierarchical regression modeling of floors individuals were willing to climb continuously. To reiterate, all psychological variables and BMI were mean-centered to avoid any confounding with sex differences in willingness. The table below shows the standardized coefficients for the variables with the 95% confidence intervals (CI) positioned below. The sign of any coefficient should be noted; a negative sign would indicate that as the variable increased willing to climb decreased.

Table 4.3 Standardized coefficients and 95% confidence intervals for the contributors to willingness to climb stairs continuously.

Variable	Step 1	Step 2	Step 3
Females < Males	-.107 -.219, .005	-.111* -.217, -.005	-.120* -.216, -.022
Age (years)	-.297*** -.411, -.187	-.233*** -.340, -.123	-.121* -.228, -.014
BMI (mean centred)	-.024 -.123, .101	.022 -.088, .124	.026 -.075, .125
Positive attitude (mean centred)		.178*** .069, .284	.151** .050, .251
Negative attitude (mean centred)		-.286*** -.394, -.177	-.051 -.172, .071
Worry about fall on stairs (mean centred)			-.317*** -.449, -.185
Worry about fall when walking (mean centred)			-.167* -.305, -.029
Change in R^2		.099***	.118***
Adjusted R^2	.095	.190	.305
Final model	$F_{3, 277}$ = 10.78***	$F_{5, 275}$ = 14.11***	$F_{7, 273}$ = 18.55***

Note. *p < .05 **p < .01 ***p < .001

On step one, the only demographic variable significantly related to willingness to climb was age; older individuals were willing to climb fewer floors continuously. In addition, the effects of sex approached significance (*p* = .06). Demographic variables explained 9.5% of variance of willingness to climb continuously in this initial model. On step two, the effects of sex became statistically reliable. Both positive and negative attitudes to regular stair climbing were associated with willingness to climb such that positive attitudes increased willingness whereas negative attitudes reduced willingness. These generalised attitudes to regular stair climbing explained a further 9.9% of the variance of willingness to climb continuously in step two. On the final step, however, there was no significant contribution from negative attitude. Instead, the specific worries about falling on the stairs, and to a lesser extent worries about falling while walking, were associated with reduced willingness to climb continuously. Fear of falling on the stairs contributed almost twice as much variance of the willingness to climb that any of the other variables. Addition of these specific fears about falling added a further 11.8% variance, with the final model explaining 30.5% of the variance of willingness to climb continuously. It is noteworthy that in this final analysis that included worry about falling, the magnitude of the coefficient for age was reduced, consistent with the strong correlation between age and worry about falling in Table 4.2. There were no contributions from BMI in any of the models.

4.5. Discussion

The results of this study revealed that all the measured variables apart from BMI were associated with willingness to climb stairs continuously. As positive attitudes towards stairs increased, the willingness to climb continuously also increased. Numerically, negative attitude, primarily fear of falling on the stairs, made the greater contribution of the psychological variables. As negativity increased, the willingness of the participants to climb stairs decreased. In addition, there were effects of the demographic variables of sex and age consistent with previous research.

It is clear in the final model that the fear of falling on stairs was a major contributor to willingness to climb as the standardized effects were twice the magnitude of any other variable measured. Fear of falling is common among elders and is related to poorer quality of life, functional disability and a case history of recent falls (Tsigganou, 2012). Elders who have high levels of fear of falling are those who may experience mobility issues in their daily life and for whom the quality of life is significantly affected by their fear as they participate in a smaller number of mobility activities (Li *et al.,* 2003). Many elders are afraid of falling although they may have never experienced a previous fall (e.g. Zijlstra *et al.,* 2009). This might be due to their experience of impaired balance or to thoughts that a fall could cause injury and therefore result in decreased activity and in an increased risk of future falls (Tsigganou, 2012). In addition, sex differences occurred regarding the worry of falling, with women reporting greater fear of falling than men. Both Yardley *et al.,* (2005) and Delbaere *et al.,* (2010) reported higher falling fears in women than men so our results relating to sex differences are consistent with previous research. Data from epidemiological research on falls indicate that for women who have experienced a fall, 65% of them had experienced it at home and 11% in the garden, while for men the percentages were 44% and 25% respectively (Poutoupnis, 2007). Fear of falling at home is thus a realistic concern not simply an unfounded worry. Of the falls that resulted in death, 10% were due to stairs.

There were consistent effects for age in the number of floors participants were willing to climb continuously, consistent with any reductions in leg strength, cardio-respiratory fitness and balance that can accompany increases in age. As noted in the final analysis, effects of age appeared to be attenuated when the specific worries about falling when walking were added to the model. Such an effect would be consistent with any perceived frailty of the participants that might also influence balance with increasing age. Similarly, the negative attitude items (hard work, hurt knees, out of breath) were not a significant contributor in the final model. These descriptors of the sensations experienced when climbing stairs exhibited substantial correlations with worries about falling when walking. They may also be indexing perceived frailty when climbing that translates into worry about falling. Nonetheless, effects of age are entirely consistent with observations of stair choice in the built environment where an escalator provides an alternative means of ascent. Older individuals were less likely to choose the stairs (Eves, 2014; Kerr, Eves & Carroll, 2001; Webb, Eves & Kerr, 2011). It is noteworthy, however, that during a three month intervention for stair climbing, those participants coded as over 65 based on appearance actually increased their response to the intervention in the second half of the intervention period relative to the first (Kerr, *et al.,* 2001). Clearly, older participants can be encouraged to climb stairs. Yardley *et al.,* (2005) and Delbaere *et al.,* (2010) reported higher fears in older participants when comparing people younger than 75 years with the older remaining sample. Our research had a greater number at the lower end (45 years was the youngest participant). Stair climbing would be a reasonable home-based exercise for people progressing towards retirement. The greater range for the age, the better we can discover facts about climbing in the elderly than possible when tested in a younger population (Chapter 3). Follow-up analysis of the number of floors participants were willing to climb revealed that those 45 to 75 years would climb 2.15 (95% CI = 1.96, 2.33) floors continuously whereas there was a drop after the age of 75 to 1.26 (95% CI = 0.98, 1.53).

There were small but consistent effects of participant's sex in the modelling of the effects on continuous climbing. Men were willing to climb more floors continuously than women, were less worried about falling on the stairs, and when walking in the environment, and had less negative attitude to stair climbing regularly in general. Nonetheless the effects of sex in modelling occurred despite mean centring the variables that differed by sex so that any effects of sex were not simply an effect of differences in the other variables. Once again, these data are consistent with observations of stair choice in the built environment. Women were less likely to choose the stairs than men (Kerr *et al.,* 2001; Webb *et al.,* 2011; Eves, 2014). One finding from the stair intervention literature is encouraging. In a study that aggregated six separate data sets, women were more responsive to the intervention than men (Webb *et al.,* 2011). As a result, a generalised tendency to avoid stairs more than men may be counteracted by greater responsiveness to messages that encourage stair climbing in women.

Combining the results here with the physiological effects of increased climbing from Chapter 3 might assist development of a potential intervention for the elderly. Ageing individuals presumably want to be healthy, fit and to avoid hypertension, strokes and heart attacks. Stair climbing improved CVD risk, reduced weight and improved cardio-respiratory fitness, as well as three of the four positive attitude items employed here. To reduce fear of falling, Zijlstra and co-workers (2009) used four main elements. First, they targeted beliefs about falling in an attempt to increase self-efficacy and reduce perceived risk. In essence, the psychological part of the information aimed at a cognitive restructuring of perceived falls risk. Here positive attitudes to stair climbing, (i.e. potential benefits of reductions in heart disease, improved weight control and maintenance of fitness), influenced willingness to climb independently of negative attitudes. Motivational interviewing is a well-established technique for changing behaviour, and consequent physiological outcomes (Rubak *et al.,* 2005). Its core technique is to 'lead' interviewees to restructure their views about a behaviour so that positive benefits, e.g. health, outweigh the potential negative outcomes, e.g. falling. The strong evidence for positive outcomes on CVD risk of increased climbing could chime with the positive attitudes of the elderly to potential benefits. In essence, the data could put scientific 'flesh' on the bones of these positive attitudes.

The second element for the intervention of Zijlstra and co-workers was realistic goal setting for physical activity. While on average, the participants here were willing to climb about two floors continuously, the participants were questioned prior to any intervention. Behaviour, and the associated self-confidence for performance, increases with repetition; even a single successful completion of stair climbing increases self-confidence afterwards, with further incremental increases with repetition (McAuley, Courneya, & Lettunich, 1991; McAuley, Lox, & Duncan, 1993). In Chapter 3, participants progressively increased their climbing every two weeks and a similar progressive approach would be required for an older population. For the elderly, the amount of climbing that would be possible would probably be less but, nonetheless, progressive increases would be the only way forward to developing stair climbing ability, the third element of Zijlstra and co-workers intervention. Progressive increases in behaviour enhance the associated beliefs that it is possible to be physically active to promote maintenance of the behaviour (McAuley *et al.,* 1991; 1993; Zijlstra *et al.,* 2009).

The final element of the intervention of Zijlstra *et al.,* (2009) was a restructuring of the home environment to reduce falls risk. Plausible strategies to reduce the fear of falling could include some simple, low-cost modifications. An increase of the illumination on the stairs would allow the elders to see the edges of the stairs more accurately. Where the stairs are uncarpeted, increasing the contrast of the edges relative to the rest of the staircase should reduce tripping risk. Placing a second banister rail so that there are rails on either side of the stairs could mitigate falling risk. Participants should feel safer, particularly when descending by using the rails to increase their stability and balance. The stairs could be fitted with an additional carpet at the bottom of the flight of stairs with cushioning underneath the carpet to minimize the potential impact of any fall. Those changes could psychologically encourage older participants to increase their stair climbing at home by reducing the perceived risk of the behaviour.

In summary, consistent effects of potential positive attitudes to regular climbing may help encourage participants about the potential health benefits of stair climbing. As stated in the introduction section, a meta-analysis by Robinson *et al.,* (2002) showed that individual home-based exercise programmes used in these studies (but not including stair climbing) reduced both falls and injuries related to falls in older people by 35%, most effectively so for those aged 80 and older. The net outcome was a reduction in injurious falls and the programme was equally effective in men and women. Our research suggests that including stair climbing could be an effective addition to fall preventions given the evidence of increased leg power. A recent stair climbing intervention in an elderly population reported increased functional fitness such that reported effort, heart rate (HR) and lactate increases during uphill walking (8% slope) were attenuated (Donath *et al.,* 2014). Importantly, Donath and colleagues reported improved balance performance after the intervention.

4.5.1. Limitations

A limitation of the study was the fact that we did not estimate the confidence about climbing stairs, i.e. their self-beliefs about climbing in general. Additionally, we did not assess how many stairs they could climb successfully without the fear of falling and/or discomfort. Finally, we did not assess the history of falls prior the questionnaire that would have allowed us to test effects in individuals prior to any fall.

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CHAPTER 5
GENERAL DISCUSSION

5.1. Summary

In summary, the main purpose of this thesis was firstly to test the effects of stair climbing on several physiological variables, namely cardio-respiratory fitness, resting cardiovascular variables, body composition and lipoprotein profiles. In the first, small scale pilot study, individuals climbed stairs at home (n=8) over a 4-week period. This proved practical with no reported problems. The pilot study (Chapter 2) revealed encouraging results. Percent body fat, systolic blood pressure (SBP) and leg power were improved at the end of the brief intervention. In order to provide stronger evidence for the effects on lipoproteins, particularly triglycerides, the subsequent study tested a larger sample (n=50). As noted in Chapter 1, only one uncontrolled study provided evidence for effects on body composition. Stair climbing improved body composition, cardio-respiratory fitness and serum lipid profiles. In addition, effects of stair climbing were tested in sedentary healthy weight and overweight volunteers. In the main, stronger effects were seen in the healthy weight sample. The second major question was to assess whether using stairs at home to increase stair climbing would have equivalent effects to stair climbing in a gym setting; the effects were similar for gym-based and home-based interventions. This study revealed that home-based and gym-based stair climbing conferred similar cardiovascular health benefits in sedentary healthy weight and overweight women. These health benefits provided strong evidence of efficacy. Home-based stair climbing may offer a cost-effective intervention for cardiovascular risk to public health. While previous studies have examined health related outcomes from stair climbing, the essential question here was ''does home based stair climbing produce physiological benefits?''. The present study showed that home-based stair climbing reduced cardiovascular disease risk factors (improved weight, percent body fat, cardio-respiratory fitness, lactate and serum lipid profiles), providing evidence for a uniquely cost effective approach for CVD risk reduction for public health in general. The subsequent final exploratory study (Chapter 4) was the first study to explore potential psychological factors that might influence the willingness of an older population to climb stairs at home. There was no evidence previously on this research area. Therefore, we set out to explore both positive and negative specific outcomes of stair climbing, and a potential barrier fear of falling, as potential determinants of willingness to climb in an older population. We assessed attitudinal statements about the outcomes of stair climbing that might be relevant to any intervention materials. Positive attitudes to the benefits of regular stair climbing and fear of falling were the major predictors of willingness to climb stairs at home in the elderly, with additional contributions from fear of falling in general while walking. This study suggested that home-based stair climbing may be a plausible exercise for older individuals if the contribution of fear of falling can be mitigated.

5.2. Stair usage interventions for public health

Raised abdominal adiposity, triglycerides, blood pressure (BP), fasting blood glucose (or diabetes) and low levels of HDL cholesterol are markers for cardio-metabolic risk (Alberti *et al.,* 2007). Of these risk markers, body fat, triglycerides and HDL cholesterol were all improved in the direction of healthier profiles by the stair intervention. Further, two of the world's leading experts on cardio-metabolic risk, Lakka and Laaksonen (2007) have argued that cardio-respiratory fitness should be added to the list of cardio-metabolic risk factors. As noted in Chapter 3, cardio-respiratory fitness is a major risk factor for CHD (Blair *et al.,* 1989; 1995; 1996; Kodama *et al.,* 2009; Lee *et al.,* 2011). The physiological benefits of this simple intervention were extensive in an ostensibly healthy population, and greater benefits could be expected in a population at greater risk.

The factors linked to cardio-metabolic risk share much in common with those that precede the onset of diabetes, as do the behavioural counter-measures, improved diet and physical activity. Diabetes is a major factor for cardio-metabolic risk (Lakka *et al.,* 2002). Given its epidemic status worldwide, better information is available on diabetes than cardio-metabolic risk prevalence. The world-wide trends demonstrate that the number of adults with diabetes have increased dramatically, almost quadrupling from 108 million in 1980 to 422 million in 2014, with a global prevalence of 4.7% in 1980 increasing to 8.5% in 2014. Part of this increment is due to the dramatic rise in type 2 diabetes related to overweight and obesity. Type 2 diabetes complications can lead to stroke, heart attack, hypertension, lost of vision and kidney failure. Half of all deaths related to type 2 diabetes appear before the age of 70 years and half of them die because of CVDs, primarily heart disease and stroke. As stated above, by measuring the post-prandial glucose levels especially in the overweight Cypriots of our study, participants should have information about the risk of developing type 2 diabetes.

The prevalence of diabetes and its related risk factors in Cyprus is shown in the table below according to the World Health Organization, Eastern Mediterranean Region Rates, (2015).

Table 5.1. Prevalence of diabetes and risk factors in Cyprus.

	Males %	Females %	Total %
Diabetes	8.9	6.7	7.8
Overweight	64.7	58.7	61.8
Obesity	22.3	26.8	24.5
Physical inactivity	29.3	41.5	35.3

Consistent with the above risk factors, by avoiding excessive weight gain and increasing physical activity with stair climbing, risk for type 2 diabetes and cardio-metabolic syndrome could be reduced. The mortality due to diabetes in Cyprus according to the World Health Organization Eastern Mediterranean Region Rates, (2015) was 50,000 people in 2000 and it is expected to rise to 87,000 in 2030. This increase would cost health services almost 40% more money for health care and treatment of diabetes in Cyprus. A simple stair climbing programmes within individual's homes would represent a relatively inexpensive method of treatment without requiring going to the gym or more formal exercise sessions.

In the UK, it has been estimated that CVD alone accounted for £6.8 billion of the National Health Service (NHS) budget in 2014 (Bhatnagar *et al.,* 2015). From a broader perspective, the direct costs of diabetes and its complications were £9.8 billion annually in 2014, accounting for approximately 10% of the total NHS expenditure (Diabetes UK, 2014). A further £9 billion has been estimated for the indirect effects of loss or reduced productivity at work to the economy (Diabetes UK, 2014). Increasing prevalence of disease, and the associated escalation in health care costs, are a major economic threat worldwide. It is well known that increased physical activity will reduce disease risk, particularly in those at greater risk from a sedentary lifestyle. What is novel about this research is that reduced risk could be achieved by individuals exercising in their own homes. This has the potential to provide a cost-effective intervention for increased risk for health service providers; there are very few costs to the NHS or to those encouraged to change their behavior.

For any health service, preliminary counselling to increase stair climbing would be required, as would an information booklet to outline the benefits and the progressive change in behaviour that was being encouraged. These elements would already be part of any programme of intervention except the briefest advice from a health care professional. Practice nurses would be a suitable professional for delivery of the intervention. For the research in Chapter 3, the experimenter contacted each participant by telephone at each time-point during the intervention where an increase in the number of daily climbs was due. This was equivalent to four telephone calls per participant. Telephone calls are low-cost elements of any intervention for the participants, particularly as climbing at home is not associated with any travelling cost to an exercise facility. Telephone calls are also low-cost to any physical activity advisor to which an individual would be allocated; they do not require 1-2-1 meetings. Telephone support increases maintenance of lifestyle changes, with greater effects the more frequent the calls (King *et al.,* 1988). Further, a long duration call is not required. Lombard, Lombard and Winett (1995) reported that a brief call touching base was as effective as a more extensive call discussing progress with participants. As noted in Chapter 3, stair climbing does not require equipment or sporting ability and is non-competitive. Most of the population can climb stairs because they already do so as part of their daily lives. Belief that one can perform the behaviour, called self-efficacy, is the major predictor of participation in physical activity. Self-efficacy is rarely a barrier to stair climbing as it can be for formal sport or jogging (Trost *et al.,* 2002). Increased stair climbing is a plausible activity for most of the population because they can already perform the behaviour. It is a truism in public health that the major predictor of future behaviour is current behaviour. Regular stair climbing at home is part of the repertoire of most of the population's current behaviour.

5.3. Potential improvements to the intervention

In terms of the intervention protocol, individuals climbed at their chosen rate. It is possible that a faster rate of climbing, if tolerated by participants, could have improved the outcomes. As noted from the study in Chapter 3, many of the people felt breathless during stair climbing especially during the final stages of their stair climbing bout, commonly known as *dyspnoea.* Shortness of breath is an inevitable consequence when climbing stairs due to metabolic demands of anaerobic rather than aerobic metabolism. The metabolic activity is increased during exercise due to an increased blood flow from the heart, i.e. cardiac output, to the working muscles (American College of Sports Medicine *et al.,* 2009). Nonetheless, increased activity of the muscles inevitably precedes the increase in oxygen supply to the working muscles. Many people who are not accustomed to exercise would inevitably feel breathless during the vigorous activity of stair climbing. Brief but intense stair climbing could improve cardio-respiratory fitness with a smaller temporal cost, as was reported recently by Allison *et al.,* (2017). It is possible that informing participants about the underlying physiology, e.g. 'You are not becoming breathless but you are becoming a bit fitter because of stair climbing', might have allowed participants to push themselves harder during the intervention (see below).

5.4. Evidence for a more extensive intervention based on stair climbing at home

Despite the simplicity of the behaviour required for the intervention, some individuals might require more support to change their behaviour. The questionnaire data in Chapter 4 provide relevant information. Zijlstra and co-workers (2009) targeted beliefs about falling and physical activity in an attempt to increase self-efficacy and reduce perceived risk in an elderly population. In essence, the psychological part of the intervention aimed at cognitive restructuring about risk and the benefits of physical activity. Motivational interviewing would be a suitable technique for facilitate behaviour change, particularly as it has proven benefits on physiological outcomes relevant to disease risk (Rubak *et al.,* 2005). To provide further information for the core technique of encouraging interviewees to restructure their views about a behaviour so that positive benefits, e.g. health, outweigh the potential negative outcomes, e.g. out of breath, an exploratory analysis of the questionnaire data was performed. By looking at individual items for the positive and negative attitudes, one can get information about potential targets during motivational interviewing that might increase willingness to climb stairs continuously. Table 5.2 summarises the mean (*SD)* for men and women on the statements for differences between the sexes.

Table 5.2. Comparison between men and women for the study's statements

Variable (statements for stair climbing)	**Men (SD) (n= 113)**	**Women (SD) (n = 168)**	**t (279)**	**Probability**
Will keep me fit	5.00 (1.72)	4.82 (1.76)	0.82	0.41
Is hard work	4.73 (1.71)	5.05 (1.54)	-1.62	0.10
Would hurt my knees	4.91 (1.65)	5.48(1.22)	-3.31	0.001
Reduces my risk of a heart attack	5.02 (1.44)	5.11 (1.36)	-0.54	0.58
Provides daily exercise	5.48 (1.27)	5.38 (1.39)	0.64	0.51
Makes me out of breath	5.16 (1.48)	5.28 (1.31)	-0.69	0.48
Will help control my weight	5.48 (1.11)	5.54 (0.95)	-0.49	0.62

As can be seen from the table, for the negative items, there was only a significant sex difference for the statement that stair climbing would 'hurt knees', with greater reports in women than men for this barrier. In addition, the statement that regular stair climbing would 'make me out of breath' was also suggestive of a higher score in women than men.

For the positive items, there was no evidence of any sex differences in the possible benefits. Therefore, any materials based on positive benefits would be gender free in that it should be effective for both sexes, i.e. gender neutral.

In addition to testing for sex differences, Pearson's product moment correlations tested for any association between the single items and age of the participant. The maximum correlation was between age and the statement that stair climbing would 'keep me fit', $r = -0.173$, $p = 0.104$. None of the correlations was significant with Bonferroni protected probabilities. As a result, the different attitudinal statements were unrelated to age and any intervention components based on these items should be age neutral.

Finally, an exploratory stepwise regression analysis was performed to test for any relationships between individual belief statements and willingness to continuously climb. As there was weak evidence of some sex differences in individual items, mean centred scores within each sex were employed to avoid any potential confounding of scores with sex as was performed in Chapter 4. The criterion for inclusion of an item in this stepwise regression was $p = 0.10$.

The table below summarises the individual items from the attitude statements that made an individual contribution to willingness to climb continuously.

Table 5.3. Contributors to willingness to climb stairs continuously.

Effect	**Coefficient**	**SE**	**t (279)**	**Probability**
Sex (M>F)	-0.30	0.14	-2.09	0.037
Age	-0.02	0.00	-3.89	< 0.001
Will keep me fit (mean centred)	0.19	0.04	4.64	< 0.001
Hurts my knees (mean centred)	-0.09	0.05	-1.70	0.089
Makes me out of breath (mean centred)	-0.15	0.05	-2.74	0.006
Helps control my weight (mean centred)	-0.13	0.07	-1.78	0.075

As can be seen from the table, the individual item with the greatest individual contribution to willingness to climb continuously was 'keep fit'; the more individuals thought regular stair climbing would keep them fit, the more floors they were willing to climb. When discussing cardio-respiratory fitness in Chapter 3, it was made explicit that improvements in cardio-respiratory fitness occurred with all previous tests of increased stair climbing in the field (Boreham *et al.,* 2000; Boreham *et al.,* 2005; Kennedy *et al.,* 2007; Meyer *et al.,* 2010). Further, relatively low volumes of increased stair climbing improved cardio-respiratory fitness; accumulations of 24 and 21 floors daily improved fitness in Kennedy *et al.,* (2007) and Meyer *et al.,* (2010) respectively. In a follow-up study to the original work of Fardy and Ilmarinen, females improved $\dot{V}O_2Max$ with only 13 extra floors.day^{-1} over 24 weeks (Ilmarinen *et al.,* 1979), but only significantly so for those at greater risk, the older (+4.8%) and less aerobically fit individuals (+6.3%). Such a low volume of stair climbing should be a plausible and achievable goal for an elderly population. If the briefer intervention duration tested by Allison *et al.,* (2017) in which individuals climb at a relatively intense rate should prove acceptable to an elderly population, a shorter temporal footprint could be obtained. Clearly, effects of stair climbing on cardio-respiratory fitness may prove a fruitful area to explore in any motivational interview. The evidence from Chapter 3 provides a strong justification for increased climbing for health. Graphical displays and links to the potential benefits of improvements in cardio-respiratory fitness on disease risk might be fruitful ways to facilitate such an interview.

Additionally, an intervention specifically in the elderly improved functional fitness such that reported effort, heart rate (HR) and lactate increases during uphill walking (8% slope) were attenuated (Donath *et al.,* 2014). Any improvements in functional fitness in those starting a climbing intervention should help to maintain any behaviour change by the perceived improvements in functional ability. Further, it should be noted that the attitude item, 'will keep me fit' was actually less positive than the actual outcome of increased stair climbing which was *improvements* in fitness. Any interview could make this outcome explicit in an attempt to improve willingness to continuously climb the stairs.

One further individual item had weak evidence of a contribution in this follow up analysis ($p = .08$), 'will help control weight'. As with the fitness outcome, the actual benefits of a decrease in weight and body fat from climbing were better than that implied by the attitudinal statement. Once again, any interview could make this outcome explicit to encourage willingness to continuously climb.

Concerning negative items, only feelings of 'making me out of breath' when climbing stairs was a significant negative contributor; the more out of breath when climbing individuals reported, the less floors they were willing to climb. Perceived shortness of breath is almost an inevitable consequence of stair climbing. As noted previously, stair climbing in the field requires 9.6 metabolic equivalents (METs), i.e. is a vigorous lifestyle physical activity (Teh & Aziz, 2002). More importantly, the brevity of a typical climb of one floor, about 15-20 sec, means that oxidative metabolism cannot supply oxygen to the exercising muscle within sufficient time to support the increased force production; typically two minutes are required for steady-state performance (McCardle, Katch & Katch, 2007). The net outcome is that anaerobic processes must be employed, incurring an oxygen debt that must be repaid. All individuals feel slightly breathless after stair climbing two floors. Indeed, the amount of breathlessness is actually a measure of the slight improvement in cardio-respiratory fitness that has resulted from that single climb. With repeated experience of climbing, sensations of breathlessness are diminished. As Eves & Hoppé (2009) pointed out the experience of breathlessness from physical activity, and a rapid heart rate, are components of the lay prototype of heart disease rather than health (Bishop 1987; Lalljee, Lamb & Carnibella, 1993). For the elderly specifically, restructuring interpretation of mild breathlessness and explanation of its origin might prove a fruitful topic during the interview to reduced potential negative effects on willingness to climb. Nonetheless, potential participants would have to be screened for suitability for any physical activity increase to ensure that 'breathlessness' when climbing was not a symptom of real underlying pathology.

Finally, the item 'hurts my knees' merits comment. Surprisingly, stair climbing entails the same ground reaction forces as walking on the level (Spanjaard *et al.,* 2007; 2008; 2009; Reeves *et al.,* 2008). It is stair descent which is associated with increased impact on the knee joint as the descender breaks their fall under the force of gravity with their leading leg (Reeve *et al.,* 2008). If the individual truly feels that that climbing hurts their knees then it is possible that climbing would not be a suitable intervention for that individual. Similarly, an individual who experiences knee pain when stair descending would be contraindicated for an intervention that required repeated ascending and descending of the stairs at home. This would be particularly true the more weight that the individual would have to decelerate when descending. Alternatively, climbing requires power from the hip and knee muscles to raise the centre of mass over the support foot so that the trailing leg is free to take the next step upwards (Warren, 1984; Riener, Rabuffetti & Frigo, 2002; Reeves *et al.,* 2008; 2009). Peak knee joint moments are up to three times those required for level walking (Reeves *et al.,* 2008; 2009). It is possible that participants were using the statement 'hurts my knees' to describe this perceived barrier. Typically, older adults alter the rate at which they climb to spread the force production more evenly over time so that adaptation to increased climbing would occur (Reeves *et al.,* 2009). Further, with repetition of stair climbing, leg strength improved for the intervention in Chapter 3. Behaviour, and the associated self-confidence for performance, increases with repetition; even a single successful completion of stair climbing increases self-confidence afterwards, with further incremental increases with repetition (McAuley, Courneya, & Lettunich, 1991; McAuley, Lox, & Duncan, 1993). Reduction in pain in any exercising muscle should accompany any increase in leg strength and power. These data could be used to explain to an interviewee that the sensation would actually be improved by any intervention in an attempt to reduce negative expected outcomes of increased stair use.

5.5. Potential measurement improvements for physiological markers

This research employed simple tests of function to assess the effects of stair climbing and potential improvements to some of the measurements for any subsequent research. For the prediction of the cardio-respiratory fitness, the $\dot{V}O_2Max$ proxy from the Multi-Stage Fitness Test (MSFT) was used (Leger & Lambert, 1982). As noted earlier, the repeated acceleration and deceleration of body mass required for the MSFT disadvantages overweight participants relative to those who are overweight. The main reason of using the MSFT was because it allowed simultaneously testing of more than one participant. Participants were tested in groups of 3-4 people. An alternative test that allows simultaneous testing of multiple participants would be the Harvard Brouha step test for predicting $\dot{V}O_2Max$ (Brouha, Heath & Graybiel, 1943). This simple test requires minimal equipment where the participant needs to step up onto, and back down again from a

50.8cm bench at a rate of 30 steps.min^{-1} until exhaustion or for five min. Although such a test, in part, mirrors the stepping activity required for stair climbing and descent, the main topic of this thesis, overweight participants would have to raise greater body mass. As a result, estimates of fitness would have been biased against the overweight participants in the sample relative to those of healthy weight. Further, this method was rejected because of its sub-maximal type of testing compared to the MSFT which provides a maximal estimate of cardio-respiratory fitness.

For the leg power assessment in Chapter 3, we used the countermovement jump (CMJ) without arm swing and the time of flight was recorded with a Bosco Ergo Jump System Mat. The height jumped in cm as an index of leg power was derived from the equations of Komi & Bosco, (1978). One alternative would be to use an isokinetic machine to evaluate the power of the lower limbs. The isokinetic machines are especially suitable for rehabilitation and they are usually used in people who are characterized by muscle weakness (Health Technology Assessment, 2014). Isokinetic dynamometry could be considered unsuitable and not appropriate for all exercisers of the present study. Half of the participants used were overweight and physically inactive. Thus, it might be a high demand test for them because a number of repetitive sets needs to be performed in order to complete this test. Therefore we did not want to cause muscle pain due to muscle tissue damage. Despite the better reliability of this test, the comfort of each participants was a main priority. In addition, isokinetic equipment may require specialised facilities, something that was not available to the research.

For the body composition analysis, skinfold measurements were used. However, the most accurate, gold standard method for body composition analysis is Dual-Energy X-RAY

Absorptiometry (DEXA Scan). The DEXA scan can be used to quantify lean body mass, bone mass, fat, and visceral (abdominal) fat. The measurement of visceral fat could be a major measurement advance on skinfold calipers. Improvement in abdominal body fat with stair climbing would be important because visceral fat correlates with other risk of diseases, such as metabolic disturbances, CVD and type 2 diabetes (Lakka *et al.*, 2002; Lakka & Laaksonen, 2007; Alberti *et al.,* 2009). One simple addition to the testing protocol would have been to measure waist circumference. Waste circumference is related to abdominal subcutaneous and visceral fat (Janssen *et al.,* 2002) and there are clear criteria for this as an indicator of cardio-metabolic disease risk (Alberti *et al.,* 2009).

In addition, some individuals, significantly so in Chapter 2 but not for the larger sample in Chapter 3, had put on weight, despite a loss of body fat measured with calipers. It appears that there was a separate training effect on fat free mass. As noted earlier, climbing stairs can improve leg strength which may reflect an increased muscle mass. In this case, the DEXA scan could explain our results with a possible indication of any increase in lean body mass in some individuals when repeating the DEXA scan post-test. Unfortunately, we were not able to use a DEXA scan because of its expense. Further, skinfold measurements can be influenced by human factors that could affect the accuracy and objectivity of the results. However the skinfold measurements were completed by an experienced professional.

For the blood measurements, fasting plasma LDL, HDL, triglycerides and glucose were processed with standard laboratory methods on a Cobas 400 plus Analyzer in a clinical laboratory. The system accuracy of these measurements is definitely unaffected according to the standards of the International Organization for Standardization (ISO) (Freckman *et al.,* 2015). To improve the assessment of metabolic functioning, however, it would be interesting to measure the post-prandial glucose levels to determine the amount of glucose in the blood after a meal (American Diabetes Association, 2001). The effects on this, of the stair climbing protocol, would be of considerable interest. To measure post-prandial responsivity, participants fast overnight and after resting measurements, a standard meal is provided and blood measurements taken every 30 minutes for the three hours following the meal. Practical reasons precluded such an approach in the thesis. Blood sugar levels normally increase after meal consumption, with greater increases in those at cardio-metabolic risk (Ceriello *et al.,* 2005). This forces the pancreas to release insulin assisting the body to remove glucose from the blood by storing it to use later for energy expenditure. Individuals with impaired glucose tolerance do not respond and/or produce insulin, and, hence, blood sugar remains elevated, with potentially damaging effects on the endothelium wall (Feener & King, 1997; American Diabetes Association, 2001). This can cause damage to blood vessels, with hyperglycemia impairing vasodilation in the vascular beds (Kawano *et al.,* 1999). Similarly, post-prandial hypertriglyceridemia, as well as hyperglycaemia, can impair vascular function in diabetic patients, with additive effects of the two increases (Ceriello *et al.,* 2005). Should we have measured post-prandial glucose and triglyceride levels, it could be particularly helpful to assess any possible post-prandial impairments in the overweight participants of the study.

5.6. Limitations

As made explicit in Chapter 3, logs of daily stair usage were not kept by participants, a departure from the protocols of Boreham and co-workers. As a result, we do not have information about the number of climbs completed by participants on a weekly basis. While this was a limitation, the extensive effects of the intervention on physiological markers make it clear that increased stair usage was likely. Nonetheless, as made explicit earlier, the less healthy profiles of the overweight participants would have allowed for greater changes in physiological variables yet, in the main, the opposite was found. Only triglycerides levels revealed a greater reduction in the overweight than healthy weight participants. It is possible that the overweight participants completed less of the total protocol than those of healthy weight. Any subsequent study should ensure that daily stair usage is logged. Although objective measurement of the behaviour would be preferable, to date, none of the objective monitors that are available can distinguish steps spent climbing and descending from walking on the level. It is possible that with advances in wearable technology, such a measure may be available in the future. If such a monitor could measure the amount of stair usage, and the speed at which it occurred, then assessment of dose-response relationships between usage and physiological outcomes would provide more fine-grained evidence for efficacy of this simple intervention.

Another limitation of the study of Chapter 3 was the fact that we did not recruit males. Cypriot males were not interested in participating in the study It was very difficult to persuade them to participate because most of them believed that *'stair climbing is just for women'* and a male cohort was precluded. It is obvious that some cultural aspects may have influenced the results. Nonetheless, Boreham, Wallace & Nevill, (2000) and Boreham *et al.,* (2005) did not recruit males either so the study was consistent with the original research on which it was based. Further, evidence from previous research (Kennedy *et al.,* 2007; Meyer *et al.,* 2010) that recruited both males and females showed significant improvements in cardio-respiratory fitness so it seems unlikely that differential effects on fitness would accrue from equivalent amounts of stair climbing. Despite this, a differential training effect in men is possible as climbing can have different effects in the sexes in observational (Shenassa *et al.,* 2007) and experimental data (Tian *et al.,* 2015)

In addition, we used an age eligibility limit for participation of 18-45 years of age; hence, it is unclear whether the positive results from stair climbing provided in our study, would have the same impact in the elderly. As the elderly are often at greater disease risk overall than younger cohorts, it seems likely that at least equivalent effects could be achieved in a population with elevated risk at baseline. Finally, women were not asked to report if they had a normal menstrual cycle between 27-32 days, nor the stage in the cycle at which intervention effects were measured. Hence, estrogens could play some role in any changes in body fat tissue and, consequently, BMI that were uncontrolled (Leeners *et al.,* 2017).

For the study reported in Chapter 4, a clear limitation was the fact that we did not estimate self confidence about climbing stairs, i.e. their self-beliefs about climbing in general. Additionally, we did not assess how many stairs they could climb successfully without the fear of falling and/or discomfort. Finally, we did not assess the history of falls prior the questionnaire that would have allowed us to test effects in individuals prior to any fall.

5.7. Conclusion

To conclude, stair climbing is a lifestyle physical activity with effects on a range of CVD risk factors. This thesis explored the potential of stair climbing at home as a public health intervention. It focused on the prospect of home-based stair climbing as a cost-effective intervention for CVD risk in public health. This simple form of exercise at home can lead to encouraging effects on people's health. Stair climbing improved body composition, cardio-respiratory fitness and serum lipid profiles as a home-based intervention. Stair climbing does not require a specific time of day to be completed, sporting ability, clothing or financial cost. People just need some motivation and time in order to reduce the CVD risk. Moreover, consistent effects of potential positive attitudes to regular climbing may help encourage participants about the potential health benefits of the behaviour. Despite all the encouraging results in this thesis, further research needs to be conducted to explore the benefits in the longer term.

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APPENDICES

Appendix 1.

INFORMATION FOR VOLUNTEERS-CONSENT FORM

You have been asked to give your consent for your participation in this research. This research is been conducted under the Doctoral Programme of Sports and Exercise Sciences of the University of Birmingham in collaboration with the Doctoral Programme of Exercise Science and Physical Education of the University of Nicosia. Before you give your consent, I would like you to read this content very carefully.

The main purpose of this study is to ascertain the effects of stair climbing on several physiological variables. We will use stair climbing as an intervention programme because of its broad use within our houses, university, at work etc.

Inclusion criteria will be females age 18-45. Volunteers will be asked not to change their diet or lifestyle over the experimental period. Data on medical history, medication use, habits and anthropometric characteristics will be obtained by using standardized questionnaire.

Subjects will be asked to fill and sign:

1. Physical activity questionnaire

2. Physical Activity Readiness Questionnaire (PAR-Q)

3. Informed consent form.

If one the following questions are not negative, then you will be excluded from participating as you will not feel the specific requirements for a healthy condition:

1. **Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?**
2. **Do you feel pain in your chest when you do physical activity?**
3. **In the past month, have you had chest pain when you were not doing physical activity?**
4. **Do you lose your balance because of dizziness or do you ever lose consciousness?**
5. **Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
6. **Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
7. **Do you know of <u>any other reason</u> why you should not do physical activity?**

After providing informed consent participants will be asked to complete the following physiological measurements.

- Athropometric characteristics (weight, height)
- Skinfold calibration for % Body fat (HARPENDEN CALIBER)
- Strength and power tests for the lower extremes (Counter movement jump- OPTO JUMP)
- Blood lipid measurements (Total Cholesterol, HDL, LDL, triglycerides, glucose, lactic acid)
- Cardiorespiratory fitness VO_2mMax test (SHUTTLE RUN TEST)
- Blood pressure and heart rate monitoring

The study will be separated into 3 intervention programmes. Each volunteer will participate in one of the following groups:

1. GR 1. SELF REPORT STUDY **AT HOME**

   Stair climbers will be asked to undergo an 8-week stair climbing programme, progressing from two ascents per day in week 1 and 2 to eight ascents per day in weeks 7 and 8, by recording their volume of climbing at home when using the stairs of their own houses. You will be asked to summarize specific amount of stairs only ascending by ascending and descending the stairs at home. Number, rate, frequency, etc. of ascending stairs will be determined individually based on the distribution of stairs in your own home.

   e.g
   If at a participant's house there are 20 stairs, 17cm of each stair, then we will do the following calculations: 3280cm/17cm = 193 stairs.
   193 stairs/20 stairs= 9.65.
   This means that you have to ascend/descend your stairs at home 9.65 times.

   Time needed
   As stated above, an 8-week stair climbing programme will take place, progressing from two ascents per day in week 1 and 2 to eight ascents per day in weeks 7 and 8. This programme will last approximately 10 minutes per day for the first 2 weeks (5+5), 15 minutes for week 3-4 (5+5+5), 20 minutes for week 5-6 (5+5+5+5), and 25 minutes for the last 2 weeks (5+5+5+5+5). Each session lasts for 5 minutes and each participant is free to chose whenever she wants to undergo the test throughout the day. This exercise is not rigorous as each participant is allowed to ascend and descend the stairs in its own rhythm and pace.

2. GR 2. LABORATORY STUDY - **STAIR MACHINE**

   Objectively measured amount of climbing with the stair trainer recorded by the researcher Stair climbers will be asked to undergo an 8-week stair climbing programme, progressing from two ascents per day in week 1 and 2 to eight ascents per day in weeks 7 and 8, when using a stair machine.

   Time needed
   This programme will last approximately 6 minutes per day for each ascent for the first 2 weeks (3+3), 9 minutes for week 3-4 (3+3+3), 12 minutes for week 5-6 (3+3+3+3), and 16 minutes for the last 2 weeks (3+3+3+3+3). Each session lasts for 3 minutes and each participant is free to chose whenever she wants to undergo the test throughout the day. This exercise is not rigorous as each participant is allowed to ascend and descend the stairs in its own rhythm and pace according to the screen on the stair machine. This type of exercise will be monitored by the researcher.

3. GR 4. CONTROL GROUP

   No intervention programme

After the 8 week intervention programme, the physiological measurements will be repeated.
All of the procedures will be in accordance with institutional guidelines and will be approved by an institutional review committee of University of Nicosia.

All the research information shared with you will be kept confidential by not discussing or sharing the research information in any form or format (e.g., disks, tapes, transcripts) with anyone other than the researcher. After data collection, all data will be encoded.

e.g

Elpida Michael's lactic acid pre test= ELMILA.1samplePRE

All research information in any form or format (e.g., disks, tapes, transcripts) will be secure while it is in my possession.

Travelling expenses would be paid to participants but no other monetary encouragement to participate will be provided. Ethical approval will be sought for this study and all participants will provide informed consent statement provided by University of Nicosia. During the test if any of participants feels unwell and cannot continue, has the right to withdraw. If you have any questions or concerns about the survey, please contact Ms Elpida Michael at 99-695776.

Thank you for your voluntary consent for participation in this research.

Dear participant,

Please read the following statements carefully and if you agree with all of them, sign below.

- I have read the information sheet about the study.
- I agree to participate and consent to my data being used.
- I know that the information that I give will be treated as confidential.
- I understand that I can withdraw from the study at any time up to the point of submission for publication with no penalty.
- I know that I may ask that any data pertaining to me be destroyed at any time up until the publication with no penalty.

I have read the text above and fully understand the procedures to be submitted. I effortlessly accept to participate in this research reserving the right to stop or withdraw at any time, according to my own judgment.

I agree to the above statements.

Name/Surname

Signature

Thank you for your voluntary consent for participation in this research!

Appendix 2.

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	**1. Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?**
☐	☐	**2. Do you feel pain in your chest when you do physical activity?**
☐	☐	**3. In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	**4. Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	**5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	**6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	**7. Do you know of <u>any other reason</u> why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to <u>all</u> PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

<u>Informed Use of the PAR-Q</u>: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ____

SIGNATURE ____ DATE ______________________________

SIGNATURE OF PARENT ________________________________ WITNESS ___________________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

Appendix 3

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE (August 2002)

SHORT LAST 7 DAYS SELF-ADMINISTERED FORMAT

FOR USE WITH YOUNG AND MIDDLE-AGED ADULTS (15-69 years)

The International Physical Activity Questionnaires (IPAQ) comprises a set of 4 questionnaires. Long (5 activity domains asked independently) and short (4 generic items) versions for use by either telephone or self-administered methods are available. The purpose of the questionnaires is to provide common instruments that can be used to obtain internationally comparable data on health–related physical activity.

Background on IPAQ

The development of an international measure for physical activity commenced in Geneva in 1998 and was followed by extensive reliability and validity testing undertaken across 12 countries (14 sites) during 2000. The final results suggest that these measures have acceptable measurement properties for use in many settings and in different languages, and are suitable for national population-based prevalence studies of participation in physical activity.

Using IPAQ

Use of the IPAQ instruments for monitoring and research purposes is encouraged. It is recommended that no changes be made to the order or wording of the questions as this will affect the psychometric properties of the instruments.

Translation from English and Cultural Adaptation

Translation from English is encouraged to facilitate worldwide use of IPAQ. Information on the availability of IPAQ in different languages can be obtained at www.ipaq.ki.se. If a new translation is undertaken we highly recommend using the prescribed back translation methods available on the IPAQ website. If possible please consider making your translated version of IPAQ available to others by contributing it to the IPAQ website. Further details on translation and cultural adaptation can be downloaded from the website.

FURTHER DEVELOPMENTS OF IPAQ

International collaboration on IPAQ is on-going and an ***International Physical Activity Prevalence Study*** is in progress. For further information see the IPAQ website.

More Information

More detailed information on the IPAQ process and the research methods used in the development of IPAQ instruments is available at www.ipaq.ki.se and Booth, M.L. (2000). *Assessment of Physical Activity: An International Perspective.* Research Quarterly for Exercise and Sport, 71 (2): s114-20. Other scientific publications and presentations on the use of IPAQ are summarized on the website.

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the last 7 days. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the vigorous activities that you did in the last 7 days. Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

1. During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, aerobics, or fast bicycling?

_____ days per week

No vigorous physical activities Skip to question 3

2. How much time did you usually spend doing vigorous physical activities on one of those days?

_____ hours per day _____ minutes per day

Don't know/Not sure

Think about all the moderate activities that you did in the last 7 days. Moderate activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the last 7 days, on how many days did you do moderate physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

_____ days per week

No moderate physical activities Skip to question 5

4. How much time did you usually spend doing moderate physical activities on one of those days?

_____ hours per day _____ minutes per day

Don't know/Not sure

Think about the time you spent walking in the last 7 days. This includes at work and at home, walking to travel from place to place, and any other walking that you have done solely for recreation, sport, exercise, or leisure.

5. During the last 7 days, on how many days did you walk for at least 10 minutes at a time?

_____ days per week   No walking   Skip to question 7

6. How much time did you usually spend walking on one of those days?

_____ hours per day _____ minutes per day

Don’t know/Not sure

The last question is about the time you spent sitting on weekdays during the last 7 days. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the last 7 days, how much time did you spend sitting on a week day?

_____ hours per day _____ minutes per day

Don’t know/Not sure

This is the end of the questionnaire, thank you for participating.

Appendix 4.

Shortened Birmingham Worksite Questionnaire

There are no right or wrong answers as we are interested in how <u>you</u> feel. All answers will be treated in the strictest confidence Please circle or tick the answer that best describes you.

Name………………………………………………. Date of birth …………… Gender M / F

1) If you work, how often do you take the stairs rather than use a lift or escalator <u>when at work</u>?

Not at all	a few times	about half the time	a lot of the time	most of the time	All of the time

2) Please circle the floor

on which you work. Ground 1^{st} 2^{nd} 3^{rd} 4^{th} 5^{th} 6^{th} 7^{th} 8^{th} 9^{th}

3) How often do you take the stairs rather than use a lift or escalator <u>outside of work</u>?

Not at all	a few times	about half the time	a lot of the time	most of the time	All of the time

4) How many floors are there in the place where you live? ………………… (insert number)

5) If you were asked to go up and down the stairs continuously in your home, how many times would you be willing to do this? (Up and down is a single journey, so if you would be willing to do this once, insert 1) ………………………..

Please indicate how much you agree or disagree with the following statements? Remember there are no right or wrong answers; we are interested in how you feel.

6) Regular stair climbing will keep me fit

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

7) I use the lifts because they are quicker than the stairs

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

8) Regular stair climbing is hard work

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

9) I am worried about falling when going up and down stairs

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

10) I am more likely to use lifts and escalators when the weather is hot

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

11) Regular stair climbing would hurt my knees

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

12) I am worried about falling when going to the shops

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

13) Regular stair climbing will reduce my risk of a heart attack

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

14) I use the escalators because they are quicker than the stairs

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

15) I am more likely to use the stair to come down than go up when there is a lift

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

16) Stair climbing provides daily exercise

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

17) I am more likely to use the stairs if I would have to wait for a lift

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

18) I am worried about falling when walking up and down slopes

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

19) Regular stair climbing makes me out of breath

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

20) I will use lifts and escalators rather than the stairs if I am carrying heavy things

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

21) I am worried about falling when walking in a place with crowds

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

22) Regular stair climbing will help control my weight

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

Thank you for completing the questionnaire