STAIR CLIMBING FOR PUBLIC HEALTH

by

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ABSTRACT

Prolonged sitting is associated with increased risk of obesity, type 2 diabetes and cardiovascular diseases. This thesis explored the effectiveness of point-of-choice prompt among university students to promote stair usage and reduce the use of the lifts and consequently their cost. This thesis also assessed on the feasibility of the employees and potential of stair climbing activity to be incorporated at the workplace. The main aims were to increase stair use and reduce prolonged sitting at work. The first study displayed posters with message based on the potential calorific expenditure from a single total ascent for four weeks at student's accommodation. Results showed no significant difference in electricity consumption during intervention for both terms (spring and autumn). Point-of-choice prompt displaying weight loss over a year with regular stair climbing based on the height of the building clearly did not promote stair usage among the students. Thus, different type of messages should be used in the future to test the interest of this target group towards stair use. The height of the building should also be considered where as higher buildings are recommended since more energy is used for the lift to reach the topmost level of the building and could generate significant difference before and after the intervention. Apart from that, this study did not measure the number of students who climbed the stairs during baseline and intervention periods as this could actually show individual response towards the point-of-choice prompt and stair use. An inconspicuous observer or a video recorder should be placed nearby to the stairwell to record the use of the stairs either by ascent or descent and to code the students by gender as well as weight status (normal weight, overweight, or obese).

Second study was a feasibility study assessing on the employees' feasibility of integrating stair climbing activity as an interruption to sitting throughout working hours, and determining the effects of intermittent stair climbing on glucose and lipid profiles. Participants were asked to climb four floors at one-hour intervals throughout eight hours working period. A pop up reminder was displayed on the participant's office desktop. Blood samples were taken pre and post intervention. Findings revealed significant improvements in fasting blood glucose, low density lipoprotein cholesterol (LDL-C) and total cholesterol (TC)/high density lipoprotein cholesterol (HDL-C) ratio in the experimental group. There was no significant difference found for triglycerides (TG) and high density lipoprotein cholesterol. This study only managed to get eight participants for control group, quite a small number of sample size. This was due to the location of the study whereas only two buildings had four and more floors. Thus, it became a restriction to other employees from other buildings to join the study. If to be repeated in the near future, bigger sample size is required to increase the precision and power of the study and selection of the study site should also be taken into account. The positive health outcomes from regular stair climbing activity and its feasibility to be performed at work could be a stepping stone to the employers to promote healthier lifestyle among their sedentary employees. Stair climbing is a vigorous physical activity, and this study showed that integrating four floors of stair climbing eight times daily on weekdays could achieve recommended physical activity for adults.

The final intervention was a laboratory based study testing on interrupted sitting at work with light intensity walking (3.0 $km.hr^{-1}$) and vigorous intensity stair climbing (60 $steps.min^{-1}$). Sitting was interrupted every 20 minutes in the seven-hour trial after the consumption of moderate fat meal. Significant improvements of triglycerides were observed after 2-hour and 5-hour tests for light intensity walking when compared to uninterrupted sitting. There was no significant difference found for triglycerides, glucose and non-esterified fatty acids (NEFA) for stair climbing in comparison with uninterrupted sitting. However, reduction in postprandial peak in plasma glucose and attenuation of the NEFA were observed. It was expected that the more intense the physical activity, the greater the effects, but the data showed otherwise. These findings could be due to the compliance of the participants towards preparing and consuming the meals the day before the testing. Participants were given the food diary to write down details of each recipe in terms of ingredients and how it was prepared to ensure the calorie intake remains the same prior to the three testing sessions. It is recommended in the future to provide the meals for the participants as their compliance could be compromised. Apart from that, participants were advised to continue with their normal routine during the six days wash-out period prior to the next testing session. Their adherence towards instruction to avoid performing any moderate and vigorous physical activities during this period could have been violated and might have affected the results. Thus, if similar study protocols are to be repeated in the future, it is recommended to send periodic reminder to the participants to maintain their customary physical activity and provide physical activity diary to monitor their daily activities. In conclusion, stair climbing can be prescribed to break prolonged sitting and reduce sedentary time hence improves employees' health.

DEDICATION

To my beloved father, who constantly inspired, motivated and believed in me along the journey. I wish you were here as I know you will be the happiest person to read my thesis.

In loving memory,

Mat Azmi bin Muhammad (3rd February 1951 ~ 2nd November 2017)

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
AUC	Area under the curve
BMI	Body mass index
CHD	Coronary heart disease
CVD	Cardiovascular disease
HDL-C	High density lipoprotein cholesterol
IDDM	Insulin dependent diabetes mellitus
IqR	Inter-quartile range
IPAQ	International physical activity questionnaire
LDL-C	Low density lipoprotein cholesterol
METs	Metabolic equivalent of task
MPH	Miles per hour
MVPA	Moderate to vigorous physical activity
NEFA	Non-esterified fatty acids
NIDDM	Non-insulin dependent diabetes mellitus
PAR-Q	Physical activity readiness questionnaire
PPI	Patient and public involvement
SRBAI	Self-report behaviour automaticity index
TC	Total cholesterol
TG	Triglycerides
OGTT	Oral glucose tolerance test
UK	United Kingdom
US	Unite States
W	Watts
WHO	World Health Organisation

CHAPTER 1

INTRODUCTION

1.1 Obesity

Overweight and obesity can be defined as an excessive amount of fat accumulated in an individual's body that may impair health. According to body mass index (BMI) formula i.e. kg/m^2, whereby kg is the weight of a person and m^2 is the height in metre squared, the BMI of a person that is 25 and more is classified as overweight and 30 and more as obese (WHO, 2013). Obesity is further classified into three types; grade 1 (BMI of 30 - <35), grade 2 (BMI of 35 - <40) and grade 3 obesity (BMI of ≥40) (Flegal, Kit, Orpana, & Graubard, 2013).

Obesity has been a public health concern for many years. In 2016, worldwide obesity has increased to 1.9 billion adults who were recorded overweight and more than 650 million obese (WHO, 2018). Specifically, the adult population in England had 26% and 27% for men and women who were obese respectively. Data from England also showed that 40% men and 30% women were recorded as overweight (Health Survey for England, 2017). The trend of increased prevalence of obesity since the 1970's until decades later has projected the estimation of obesity in the year 2030 to be 65 million more among US adults and 11 million more obese adults in the UK (Wang, McPherson, Marsh, Gortmaker & Brown, 2011).

Excess body fat mass is known to be associated with metabolic abnormalities (Bastien, Poirier, Lemieux, & Després, 2014) and may lead to several health problems (David & Amy, 2013). Obesity is also a risk factor for coronary heart disease, stroke, type 2 diabetes, certain cancers, low back pain and respiratory diseases such as asthma and pneumonia (Artham, Lavie, Milani, & Ventura, 2009; Mokdad et al., 2001; WHO, 2000; Zammit, Liddicoat, Moonsie, & Makker, 2010). Furthermore, obesity has also been linked to depression and anxiety in comparison with healthy weight individuals (Onyike, Crum, Lee, Lyketsos, & Eaton, 2003; Simon et al., 2006).

Obesity has a greater impact on morbidity than mortality. Obesity related cardiovascular disease and obesity related type 2 diabetes have shown to increase the number of obese people with functional disabilities (Visscher & Seidell, 2001). Restricted physical movement to perform daily routine and other activities such as walking and stair climbing were recorded among obese individuals (Forhan & Gill, 2013). In terms of economic burden, obese employees were shown to contribute a greater loss to company productivity and increased medical expenses due to constrained activity and absence from work (Gates, Succop, Brehm, Gillespie, & Sommers, 2008; Goettler, Grosse, & Sonntag, 2017).

Various approaches to develop population based strategies have been taken to tackle the global issues of obesity and thus, to reduce the cost of treating obesity-related conditions. As highlighted by Sacks, Swinburn, & Lawrence (2009), the effectiveness of public health strategies towards the prevention of obesity should focus on three aspects; healthy food environment, behaviour modification of eating habits and physical activity, and implementation of health services. Low physical activity has been reported among obese individuals when compared to those who are of healthy weight. People who are obese tend to have a more sedentary lifestyle, perform less vigorous activity and generally less active (Al-Hazzaa, Abahussain, Al-Sobayel, Qahwaji, & Musaiger, 2012; Mushtaq et al., 2011). Thus, lifestyle modification in obese people is a requirement for improvement. According to Goodpaster et al. (2010), obese people who are consuming a lower calorie diet and routinely increase their physical activity will have the chance to lose weight. It is suggested to put the effort in performing moderate intensity brisk walking for 150 minutes weekly with total of 700 kcal.week^{-1} of energy expenditure or accumulate 10 to 15 minutes short bouts daily with healthy lifestyle activities such as stair climbing (Diabetes Prevention Program Research Group, 2002).

1.2 Sedentary behaviour

1.2.1 Definition of Sedentary Behaviour

Sedentary is originally taken from Latin word *sedere* which means 'to sit'. Sedentary behaviour is best referred to sitting or in reclining posture with energy expenditure of 1.5 METs or less (Mansoubi et al., 2015). Pate, O'Neill, & Lobelo (2008) stated in detail that sedentary behaviour includes activities with threshold of ≤1.5 METs and these activities involved sitting, lying back and taking a long nap. Pattern of body movement in sedentary behaviour is relatively homogenous. As described by Tremblay (2010), sedentary behaviour can be divided into four components based on the acronym SITT (sedentary bout frequency, interruptions to sedentary behaviour, time spent being sedentary, and type of activities done while being sedentary). Sedentary behaviour is different from physical inactivity. Sedentary behaviour can be further classified into: 1) being sedentary when a person is attached to a specific behaviour such as watching television or playing video games, 2) prolonged sitting due to work demand or while commuting by public transportation, and 3) not doing anything and spent most of the time sitting throughout the day (Healy et al., 2011). The patterns of activity in population-wide surveys during the past decade suggested that physical activities at work, home, during holidays and on transit were declining due to prolonged sitting, thus, increasing sedentary time at a population level (Brownson, Boehmer, & Luke, 2005). In addition, Dong, Block, & Mandel (2004) revealed a ranking of most common sedentary activities with energy expenditure of 1.5 METs or less; sitting at work (9.2%), eating while sitting (5.3%) and sitting while talking on the phone (3.8%).

The definition used to describe physical inactivity is by not fulfilling any of these criteria; 1) performed total of 150 minutes of moderate physical activity per week, 2) engaged in 20 minutes of vigorous physical activity at least for three days in a week, or 3) cumulative of moderate and vigorous physical activities which equivalent to 600 METs (Hallal et al., 2012). It has been estimated that physical inactivity is the 10th leading cause of death worldwide (WHO, 2010). The World Health Organization has listed main causes of obesity including increased daily intake of high fat foods, physical inactivity and the use of non-active modes of transportation (WHO, 2013). Individuals with energy expenditure less than 2000kcal per week (Paffenbarger, Hyde, Wing, & Hsieh, 1986) or who did not perform recommended physical activity guidelines (Lowry, Wechsler, Galuska, Fulton, & Kann, 2002) were categorized as insufficiently active.

1.2.2 Measurement of Sedentary Behaviour

Sedentary behaviour can be assessed using subjective measures (questionnaires and interviews) and objective measures (based on movement counts or posture transition) (Kang & Rowe, 2015). A number of questionnaires have been used to assess time being sedentary. As example, The Sedentary Behaviour Questionnaire (Rosenberg et al., 2010) measures time spent siting in nine behaviours (watching TV, sitting, answering phone call, and during non-active transportation) on weekdays and weekends. The Marshall Sitting Questionnaire (Marshall et al., 2010) consists of five domains focussing on occupational sitting and screen time at home. The measurement tool that can be used to specifically measure prolonged sitting at work is the Occupational Sitting and Physical Activity Questionnaire (OSPAQ). This questionnaire assesses total working hours for the past seven days and total number of days at work. It measures time spent sitting, walking and standing throughout the working hours to get to the total sedentary time spent at work (Chau et al., 2012).

Objectively measured sedentary behaviour involves the measurement of individual's bodily movement based on the total activity counts using an accelerometer. Accelerometer provides the magnitude of the acceleration within a time period that has been set which then translated into activity counts. Total counts of less than 100 within one minute is associated with sedentary behaviour (Kang & Rowe, 2015). Accelerometer is worn either on the wrist or waist. Example of the device that comprises of an accelerometer is Actigraph. Another type of device that is used to detect changes of body position is activPAL. ActivPAL is capable of assessing motion in the vertical, horizontal and anterior-posterior plane such as from sitting to standing as well as from standing to walking (Grant, Ryan, Tigbe, & Granat, 2006).

1.2.3 Occupational Sedentary Behaviour

Full time workers were shown to have longer sitting hours and shorter standing time compared to non-workers since the latter were not bound to the desk jobs such as at the workstation. Sedentary behaviour on weekdays accounted for more than 80% among workers, with approximately 20 to 40 minutes of continuous sitting prior to break (Kirk et al., 2016; Parry & Straker, 2013). Similarly, Waters et al. (2016) studied non-academic employees in a public university. Findings from self-reported and accelerometer measurement showed 77% of the participants spent their time doing sedentary activities throughout their working hours with accumulated sitting time of 480 minutes daily. In parallel, Dall, Stevenson, Henderson, & Grant (2013) reported similar outcomes whereas employees spent more time sitting during working days compared to non-working days and showed less time walking during working hours.

In this technological era, the number of physically active tasks needed to manually produce products has shrunk and been replaced by automated machines (French, Story, & Jeffery, 2001). Furthermore, easy access to high speed internet provides a convenient approach towards information gathering and services at everyone's fingertips (Studebaker & Murphy, 2014). This results in increasing the amount of time spent in front of the screen and enhanced sedentary behaviour especially among workers who dealt with online and desk bound tasks (Gilson et al., 2009). Office workers were reported to have more than 80% of sedentary time across working hours with sedentary bouts (prolonged, uninterrupted sitting) of more than 30 minutes and less breaks from sitting compared to their time outside the workplace (Parry & Straker, 2013).

The built environment in the workplace has shifted into modern designs where workers are bound to move less and sit more. In the 1980's, only 20% of workers in US were assigned with light activities at the workplace which was predominantly sitting at a desk and 30% of them were in high physically activity tasks. However, the pattern of workers with light activity at the office had increased by the year 2000. For every 10 workers, 40% of them were attached to the desk bound tasks and later in 2003, the percentage of workers who were occupied with computer jobs increased to 60% (Neville Owen, Sparling, Healy, Dunstan, & Matthews, 2010). However, the type of occupation could also influence sedentary behaviour at work. Objectively measured sedentary time among blue-collar and white-collar employees yielded time spent in sedentary behaviour were 44% and 76-80% respectively. Blue-collar employees who were construction and factory workers had greater percentage in light (49%) and moderate intensity PA (7%) than the white-collar employees (18-30% and 3-5% respectively).

Long working hours among office workers has also increased the lifestyle of being sedentary. Office workers on average spent up to 10 hours in the workplace doing routine tasks causing their movement to be limited and increasing sedentary bouts. Bound to the chair during meetings, operating machines, reading thoroughly through documents or files and focusing on the screen were the contributing factors for sedentary behaviour (Inyang, 2015). Added to this, long periods of driving in a car on the way home after work due to heavy traffic put them into further risk of being sedentary. Annually, typical total hours spent in a car in 2008 was 26 hours compared to the seven hours in the 1980’s (Schrank & Lomax, 2011).

A qualitative research was conducted among 23 overweight and obese participants with the mean age of 52 recruited from three health care centres in Barcelona. Semi-structured interviews comprised of questions on time spent sitting, activities performed during sitting, willingness to reduce sitting time, barriers and suggestion for behaviour change were conducted individually and in groups. Participants were categorised based on these occupational profiles, i.e. sedentary employees, retired or full time housewives, and students. Activities involved while sitting were using computers at work (replying emails, searching for information), driving to work, long hours of lectures, watching TV, eating, reading, and stitching. As mentioned by one of the participants, "*I am one of those people that have to spend many hours sitting because of the nature of my work; I am a computer programmer*". Participants did not aware that prolonged sitting could jeopardise their health and did not realise the importance of reducing this behaviour. Nature of a work with deskbound tasks and technology dependence (computers and machines) were found to be the barriers in reducing sitting time. However, participants were willing to change provided there are alternatives to sitting that they could enjoy and sustain to improve their sedentary lifestyle at work. Activities suggested were standing while communicating with colleagues and answering phone calls, use more stairs at work and walk to destination (Martinez-Ramos et al., 2015).

1.3 Sedentary behaviour and disease

As stated by Brannon, Feist, & Updegraff (2007), sedentariness of lifestyle is an associated factor for diseases that have caused most deaths among the people living in the current century. Prolonged sitting time has shown to be associated with overweight and obesity (Mummery, Schofield, Steele, Eakin, & Brown, 2005). According to the prospective cohort conducted from 2002-2010 involving 5,285 of sedentary workers, increased sitting time was associated with higher BMI (Lin, Courtney, Lombardi, & Verma, 2015). Similarly, higher prevalence of overweight and obesity were observed among employees who sit more than 6-hours at work when compared to the full time housewives with young children at home (Brown, Miller, & Miller, 2003). Prolonged sitting at work of 352 minutes and more throughout office hours increased the risk by 2.7 times of having waist circumference of ≥ 94 cm and 80 cm in men and women respectively and 9.0 times of BMI of ≥ 30 (Ryde, Brown, Peeters, Gilson, & Brown, 2013). Occupational sitting has also been linked to type 2 diabetes and cardiovascular diseases (Proper, Singh, van Mechelen, & Chinapaw, 2011) and the metabolic syndrome (Edwardson et al., 2012). In parallel, systematic review by van Uffelen et al (2010) showed that occupational sitting was found to be associated with BMI and waist circumference in 5 out of 10 studies reviewed. Total of five from 17 papers reviewed on occupational sitting and cancers, had yielded greater risk of breast cancer, ovarian cancer, and colorectal cancer. Majority of the papers reviewed also showed positive associations with cardiovascular disease and diabetes mellitus. More than half of the papers reviewed reported increased mortality risk due to occupational sitting. However, van Uffelen and colleagues concluded that more research is needed to strengthen the evidence between occupational sitting and health risk.

1.3.1 Sedentary behaviour and obesity

Average hours of a family in US committed in continuous television watching were eight hours a day while individual television viewing was approximately four hours. It was the highest total hours of television time recorded compared to the 1950's era (David, Hollie, & Joseph, 2008). The amount of time spent watching television is independently associated with lower level of physical activity with regards to the energy expenditure ≤1.5 METs, thus categorized as sedentary behaviour (Rhodes, Mark, & Temme, 2012). Sedentariness may cause obesity (Chau, van der Ploeg, Merom, Chey, & Bauman, 2012). Sedentary habits like long hour of screen time such as watching television, playing video or computer games (Salmon, Tremblay, Marshall, & Hume, 2011; Shields & Tremblay, 2008) and long occupational sitting (Mummery, Schofield, Steele, Eakin, & Brown, 2005) have been linked to obesity. Long hours of television viewing occupy one's leisure time that could be utilized for exercise and burn calories to get active and avoid obesity (David, Hollie & Joseph, 2008).

A study conducted in an Australian adult population by Thorp, Healy, Owen, & Salmon (2010) revealed that sitting and television viewing were significantly associated with increased BMI and reported as contributing factor towards overweight and obesity. Similar findings were reported among Canadian residents based on 2007 Canadian Community Survey whereby the frequency of obesity was found to be greater in people who spent more than 21 hours watching TV in a week compared to the other group who watched less than five hours per week (Shields & Tremblay, 2008). Shield and Tremblay (2008) also reported frequent prolonged use of computers (11 hours and more weekly) increased prevalence of obesity in men and women in comparison with five hours and less for a week. Additionally, a study conducted among Japanese adults aged 30 years and above reported individuals with insufficient physical activity and higher screen time were 1.5 times more likely overweight in comparison with those who performed sufficient physical activity and low screen time (Liao et al., 2011). For every one hour of time spent for sedentary activity, the risk of being overweight increased by 13%.

1.3.2 Sedentary behaviour and type 2 diabetes

Diabetes mellitus is a metabolic disorder featuring increased glucose in blood plasma with disturbed metabolism of carbohydrate, fat and protein either due to not enough insulin secretion or a defect of its action (Alberti & Zimmet, 1998). A person is diagnosed with diabetes when oral glucose tolerance test (OGTT) shows concentration of fasting plasma glucose is ≥ 7.8 $mmol.L^{-1}$ or plasma glucose concentration two hours after meal is ≥ 11.1 $mmol.L^{-1}$ (Colberg et al., 2010). Risk factors for insulin dependent diabetes mellitus (IDDM) or also known as type 2 diabetes are high blood pressure, overweight, high alcohol intake, increase in age, and sedentary lifestyle. Systematic reviews of 10 studies showed that more than 100% greater relative risk linked sedentary behaviour with type 2 diabetes (Hamilton, Hamilton, & Zderic, 2014).

In a sedentary state such as prolonged screen based media, sitting and reading time, our body needs to adapt to the increased workload in absorbing sugar and producing insulin after meal due to minimum energy expenditure. This may also cause distress to the cells in the pancreas which function to make insulin. In other words, sedentary behaviour triggers insulin resistance and impaired tolerance to glucose that may later progress to type 2 diabetes (Brannon & Feist, 2007). Total screen time of two hours per day was linked to the development of type 2 diabetes (14%) and a further 7% for every increment of two hours daily of continuous sitting in the office (Hu, Li, Colditz, Willett & Manson, 2003).

1.3.3 Sedentary behaviour and cardiovascular diseases

Cardiovascular diseases (CVD) involve diseases of heart and blood vessels. As stated by World Health Organization (2012), CVD has affected more than 30% of worldwide deaths, equating to 17 million of deaths per year. The contributing factors to CVD were smoking, unhealthy daily food intake, low physical activity, obesity and sedentary lifestyle (Centritto et al., 2009; Ford & Casperen, 2012; Power, Pinto Pereira, Law, & Ki, 2014).

Sedentary behaviour occurs in many perspectives: type of jobs, domestic, leisure time and modes of transportation (Ford & Caspersen, 2012). Occupational studies on sedentary behaviour and cardiovascular diseases have started as early as the 1950's. A comparison for the level of sedentary at work was made between bus drivers and bus conductors. Bus drivers with longer sitting time than conductors were found to have doubled the risk of developing coronary heart disease (CHD) as bus conductors would generally have repeated bouts of stair climbing (Morris & Crawford,1958). Rosengren, Anderson & Wilhelmsen (1991) also reported that bus and tram drivers had three times greater risk of CHD compared to other jobs due to prolonged sitting during shifts. In a similar study, male civil employers and post office workers were grouped into sedentary, intermediate and high physical activity based on their job scope and tasks. Results revealed that employees in the sedentary group showed the highest risk of developing CHD (Morris, Heady, Raffle, Roberts, & Parks, 1953).

Leisure time such as watching television and playing video or computer games were also found to be associated with cardiovascular diseases (Ford & Caspersen, 2012). Cardiovascular disease risk was found to be lowest among people who had part of their daily schedule devoted to exercise whereas individuals who were bound to the couch with leisure time filled with sedentary behaviour had greater risk of developing cardiovascular diseases (Maddison et al., 2016). A longitudinal study was conducted by Chomistek et al. (2013) on women with age ranging from 50 to 79 years old who were absence from CVD at baseline. Participants were seen after 20 years for follow up. Participants with prolonged sedentary time (sitting) were found to be overweight and had greater incidence of CVD compared to those who remained a healthy weight.

In summary, apparent relationship between sedentary behaviour and cardiovascular risk factors were reported in a number of research. Increased in sedentary time was shown to be associated with higher systolic blood pressure in patients diagnosed with hypertension (Gerage et al., 2015). Upon any extra hour of prolonged sitting among severely obese individuals, the risk of developing hypertension increased by 14% (King et al., 2016). The elevation of systolic blood pressure has been noted as a major risk factor for coronary heart disease, arterial fibrillation as well as heart failure (Drozdz & Kawecka-Jaszcs, 2014). Hypertensive heart disease affects not only vascular but also myocardial functions. It involves changes in several mechanisms such as endothelial dysfunction and constriction of coronary arteries that may lead to myocardial infarction (Raman, 2010).

1.3.4 Sedentary behaviour and metabolic syndrome

Metabolic syndrome by definition is a combination of at least three of the following key features; abdominal obesity, low high density lipoprotein (<1.03 $mmol.L^{-1}$ in males, <1.29 $mmol.L^{-1}$ in females), high triglycerides (≥1.7 $mmol.L^{-1}$), high fasting blood sugar >5.6 $mmol.L^{-1}$) or diabetes, and elevated blood pressure (≥130/85 mmHg) (Alberti, Zimmet, & Shaw, 2006). Prevalence of metabolic syndrome ranges from less than 10% and up to 84% across different countries in the world (Kolovou, Anagnostopoulou, Salpea, & Mikhailidis, 2007). It is significantly associated with socioeconomic status, sedentary behaviour, and high BMI (Cameron, Shaw, & Zimmet, 2004). In addition, Brocklebank, Falconer, Page, Perry, & Cooper (2015) found association between total sedentary time with impaired insulin sensitivity and type 2 diabetes, and effect of sedentary breaks on triglycerides.

A survey was conducted among rural population in China by Nantong Metabolic Syndrome Study on nearly 25 thousand participants. The findings revealed that individuals who slept eight hours a day have showed increase concentration of blood glucose and lipid. The same study also revealed that accumulation of sitting behaviour more than 42 hours per week contributed to 12% risk of having metabolic syndrome with features of abdominal obesity, raised diastolic blood pressure and also increased triglycerides and glucose (Xiao et al., 2016). In agreement, the data retrieved from National Health and Nutrition Examination Survey (NHANES, 2003-2006), individuals with metabolic syndrome spent more time sitting with less sedentary breaks and lower intensity of physical activity measured using accelerometer (Healy, Matthews, Dunstan, Winkler, & Owen, 2011). As sedentary time increases, the greater the risk of having metabolic syndrome (Edwardson et al., 2012).

1.3.5 Sedentary behaviour and other health outcomes

Sedentary behaviour also has impact on other health outcomes such as vitamin D deficiency and changes in muscle capacity and strength and skin appearance with notable face deposits especially around the eye folds (Inyang, 2015). Restricted exposure time of ultra violet B (UVB) may cause reduction in production of vitamin D by the body. Vitamin D is formed by the mechanism when UVB rays reach the skin and react with 7-dehydrocholesterol (7-DHC) present in the epidermis. Not enough vitamin D will lead to bone diseases and other health problems such as osteoarthritis and hypertension (Mascitelli, Goldstein, & Pezzetta, 2010).

Muscle wasting is one of the consequences of sedentary behaviour. People who spent more than five hours daily during their leisure time sitting uninterrupted tend to lose muscle strength at about 1% each day (Dong, Block & Mandel, 2004). Other health problems that occurred among sedentary individuals were unpleasant body odour, yellowish cholesterol deposits on the skin, skin rashes and itchiness (Moore, Gierach, Schatzkin, & Matthews, 2010).

The study conducted by the National Centres of Disease Control among adult US population via National Health and Nutrition Examination Survey (NHANES) reported that prevalence of decrease BMD was higher among women with sedentary behaviour (Chastin & Granat, 2010). Additionally, study among post-menopausal women who had their BMD measured and were grouped into three; osteoporosis, osteopenia, and normal bone density showed that women who had sedentary lifestyle and prolonged sitting time were found to be higher in osteoporosis group than the other two groups (Dallanezi et al., 2016).

1.4 Sedentary breaks intervention in laboratory settings

As prolonged uninterrupted bouts increased the risk of cardiovascular and metabolic diseases (Healy et al., 2008; Healy, Matthews, Dunstan, Winkler, & Owen, 2011), studies have examined whether short intermittent breaks were introduced to lower the risks. A randomised cross-over control trial was conducted among 34 overweight adults. Light intensity walking (3 $km.hr^{-1}$) on a treadmill for five minutes every 30 minutes yielded significant reduction in blood glucose postprandially (McCarthy et al., 2017). A similar effect was also found among post-menopausal overweight women with high-risk of type 2 diabetes (Henson et al., 2015) after performing similar physical activity as conducted by McCarthy et al. (2017) in a 7.5 hour protocol. Additionally, significant reductions in glucose by light intensity walking interruptions have been reported in an equivalent sized sample of 40 year old sedentary men (two minutes every 20 minutes at 2 mph) in a three-intervention experimental study with a cross over design (Pulsford, Blackwell, Hillsdon, & Kos, 2017).

In comparison of postprandial glucose concentration between sitting uninterrupted, interrupted sitting with two minutes of standing, light intensity walking and moderate intensity walking in another laboratory setting. Three supervised laboratory based trials among sedentary overweight/obese adults with age ranging from 45 to 75 years old were conducted. The response were seen to be lowest in moderate intensity walking when compared to other conditions even though the sample size was relatively small ($n < 10$ for each condition) (Larsen et al., 2017). In a randomised crossover trial, moderate intensity interruptions to sitting have previously been reported to reduce glycaemia postprandially when walking at 5.8 to 6.4 $km.hr^{-1}$ every 20 minutes in an equivalent sized sample ($n = 19$) of overweight, older individuals (54 years; fasting glucose 5mmol.L^{-1}) (Dunstan et al., 2012) in a seven-hour trial. As noted by Dunstan et al. (2012), even with regular physical activity of light intensity walking for two minutes, postprandial glycaemia was improved. Using similar study design as Dunstan and co-workers, Peddie et al., (2013) reported that accumulated short bouts of physical activity was more effective than one continuous bout especially in reducing postprandial glycaemia and insulinemia in healthy weight adults (n = 70) in the three 9-hour interventions. The intervention involved regular walking for one minute and 40 seconds every 30 minutes, and one session of continuous walking for 30 minutes in the nine-hour trial. However, none of the studies mentioned above included vigorous physical activity in comparison with sitting uninterrupted and light intensity physical activity.

In a balanced crossover trials, total of 18 female participants involved in the four-hour laboratory testing. Sitting was interrupted five times by six minutes of vigorous physical activity (ergometer cycling at 70% VO_2max), and lipoproteins measured before and after the four-hour session. Participants who were young adults with healthy weight showed improvements in high density lipoprotein cholesterol (HDL-C), total cholesterol (TC) and triacylglycerol (TAG) levels compared to the uninterrupted sitting (Engeroff, Füzéki, Vogt, & Banzer, 2017). Nonetheless, tests on a similar target group reported that lipid profiles were not affected after two minutes of light intensity walking every 20 minutes in the five-hour testing period (Henson et al., 2015). Peddie et al. (2013) also reported no differences between intermittent brisk walking and uninterrupted sitting; it was only the continuous 30-minute bout of brisk walking occurring prior to any meal that reduced triglycerides postprandially. Breaks with higher energy expenditure was shown to give greater effects on blood glucose (Larsen et al., 2017). Additionally, a higher intensity of physical activity occurring the day before test meals was also shown to be more efficient in reducing postprandial triglycerides than moderate intensity activity. Concerning intensity, Durstine et al. (2001) noted that intensity of the exercise was reflected in a dose-response relationship with blood lipids. The greater intensity of physical activity performed, the more reduction of triglycerides was observed.

1.5 Sedentary breaks intervention at worksite

The advancement of technologies has shifted the nature of work from physical labour to sedentary and mental work. Thus, various approaches have been made targeting sedentary staff in order to break the sedentary behaviour at the workplace. Interventions should focus on building a new environment such as the use of modern technology and equipment (from passive to active) at the workplace; 1) convert static desk into active work station such as sit-to-stand or treadmill desk (Alkhajah et al., 2012), 2) introduce sedentary breaks throughout working hours to ensure presence of regular breaks from sitting (McAlpine, Manohar, McCrady, Hensrud, & Levine, 2007), 3) application of prompt message displayed on the screen to remind the staff to take a break either by standing or moving (Evans et al., 2012), and 4) initiate routines against the norm such as standing during telephone calls, meetings and discussions (Commissaris, Douwes, Schoenmaker, & De Korte, 2006). In line with this, National Institute for Health and Excellence provides guidelines in promoting physical activity in the workplace. The guidelines involve development of policy, planning of physical activity programs at work, as well as implementing and monitoring the activities. Employees are encouraged to sit less and move around more in the office and advised to walk to the external meetings. Active mode of transportation or active travel (walking or cycling) is recommended. Apart from that, employees are also encouraged to use stairs to increase physical activity during working period (NICE, 2008).

1.5.1 Sit-to-stand; a minimal intervention

Manufactured sit-to-stand workstations have been implemented to be used by desk based employees with the purpose to reduce sedentary time due to prolonged sitting. Various studies have shown positive outcomes in reducing sedentary sitting by replacing the static desk with an active workstation (Alkhajah et al., 2012; Neuhaus, Healy, Dunstan, Owen, & Eakin, 2014; Straker, Abbott, Heiden, Mathiassen, & Toomingas, 2013).

Sit-to-stand workstations were installed to be used by 14 sedentary Australian office workers and assessments were made at one week and three months' follow-up. Sedentary behaviour and physical activities were measured by activPAL3. Significant reduction in sitting time by 143 mins.day^{-1} at work was reported (Alkhajah et al., 2012). Another worksite intervention on Australian employees were performed by Gilson, Suppini, Ryde, Brown, & Brown (2012) that used sit-to-stand as hot desks installed at the open office space area. Employees were allowed to use the hot desks at anytime throughout working hours. Individual's sedentary time was reduced by 5.9 - 6.4% during intervention.

A study conducted among UK employees using active workstation that allows position of sitting and standing while working also showed significant decrease in occupational sitting time at the first week, sixth week and third month with 88 minutes, 59 minutes and 44 minutes respectively and an increase in standing and light physical activities when compared to the baseline (Mansoubi, Pearson, Biddle, & Clemes, 2016). A multicomponent intervention was introduced by Healy et al. (2013) involving organisation, environment and individual approach with '*Stand up, sit less, move more*' strategy. Australian employers were consulted to obtain support and approval was granted for the modification of the workstation. Sit-stand workstations were installed and employees had a 30-minute face-to-face consultation plus one telephone call per week during the four-week intervention. Employees were recommended to stand every 30 minutes to break the sedentary sitting. Substantial reduction in sitting time was recorded by 125 minutes throughout the eight-hour working period which was exclusively replaced with standing (127 minutes) (Healy et al., 2013). Additionally, implementation of sit-stand devices in the 'take-a-stand' project for four weeks, not only reduced occupational sitting by 224% which equated to 66 mins.day^{-1} but also was reported to diminish neck pain and improve employees' mood (Pronk, Katz, Lowry, & Payfer, 2012).

1.5.2 Treadmill and cycling as more active intervention

Another innovation for active workstation was a treadmill desk. This workstation was built by incorporating a treadmill into a standing desk. Employees were working in a standing position while walking at a slow pace and changes on daily sedentary time measured by accelerometers, working performance and weight loss were observed at 6th and 12th months after the intervention started. Significantly, daily physical activity was recorded to increase while sedentary time was reduced by 43 mins.day^{-1} without affecting work routine (Koepp et al., 2013). Ben-Ner, Hamann, Koepp, Manohar, & Levine (2014) conducted a 12-month intervention at a financial company in the US by placing a working station in front of a treadmill. The speed was set in between 0 to 2 mph; which 0 mph was for standing while working. The results showed improvements in work performance, productivity and communication with other colleagues. Daily energy expenditure was recorded to increase by >74 kcal with increased time of being active, 110.7 $mins.day^{-1}$, further, an increase of energy expenditure of $100kcal.hr^{-1}$ was observed in obese sedentary employees from walking on a treadmill at 1.1 mph (Levine & Miller, 2007).

Despite standing and walking, Carr, Walaska, & Marcus (2012) came up with a creative idea of introducing pedal machines to allow the movement of lower extremities while completing their job. Employees spent more than 10 days in a month and approximately 23 minutes daily pedalling while working. Perhaps surprisingly, employees found this intervention was feasible, although statistically no difference was found in time spent sitting, standing and/or walking compared to baseline. Cycling as moderate intensity physical activity if performed half hourly at work could fulfil the requirement of the minimum physical activity recommendation. As reported by Koren, Pišot, & Šimunič (2016), office employees preferred to cycle while working rather than exercise after office hours. Employees showed increased productivity in work, i.e. typing time improved by 7.3% and 8.9% at 40 and 80 W respectively with typing errors remained unchanged.

Another intervention method to place a stepping device underneath the office desk to promote physical activity among sedentary employees (McAlpine et al., 2007). McAlphine and co-workers found that integrating the stepping activity at work while answering a telephone call, going through documents, communicating with colleagues, as well as during lunch break improved energy expenditure by 235 $kcal.hr^{-1}$ and was found to be greater in obese employees, 335 $kcal.hr^{-1}$. Thus, consistent replacing sitting with stepping for two hours daily could possibly result in 20 kg weight loss in a year with balanced energy intake.

1.5.3 Prompts at the desk

Evans et al. (2012) reported that health education on sedentary behaviour, accompanied by message prompting software that displayed a reminder with health messages on the computer screen to workers to take a break every 30 minutes of sitting, was shown to be more effective in breaking the sedentary time compared to the health education alone. A similar study by Donath, Faude, Schefer, Roth, & Zahner (2015) used a cost-effective, pop up window on workers' office computer. Three different types of messages including 'what' and 'how' components were displayed at three time points daily for 12 weeks. The messages appeared as; '*Prolonged sitting is harmful'*, *'change working position*', and *'lift up your working desk'*. Post intervention results showed significant reduction of occupational sitting of approximately 30 minutes daily among workers. Similarly, the use of e-health messages to target office workers was found to be efficient in engaging them to perform physical activity in between sedentary bouts, thus, increasing energy expenditure during weekdays (Pedersen, Cooley, & Mainsbridge, 2014).

It was suggested by Brawley & Latimer (2007), the health messages to encourage interrupted sitting need to be informative, persuasive and convincing to assure their effectiveness and adherence by the target group. Ideally, the messages should also be tailored to match a specific individual's problem or concern in order to stimulate changes in behaviour and improve quality of life (Bull, Kreuter, & Scharff, 1999). In agreement, Brawley & Latimer (2007) mentioned that messages not only should consist of what to do, but also need to highlight the components of how and why in order to convey the importance of the action and why it is recommended. The key factor for the messages to get attended was the frequency of their appearance on the screen. It should be kept to effective minimum to avoid employee ignoring the message and also reduce interruption to the workers (Bull, Kreuter, & Scharff, 1999).

Prompt message could also be used to remind employees to go against the norm of workplace practice to shorten the sedentary bouts. Normally, office workers regardless of position in the organizational hierarchy will be sitting throughout meeting hours. As suggested by Commissaris et al. (2006), the policy of a workplace can be altered to cater for a 15-minute short bout for physical activity such as standing during meeting and while answering phone calls to combat sedentary behaviour among staff.

1.5.4 Effectiveness of workplace interventions

A number of systematic review based on the literature regarding the interventions at work in reducing occupational sitting time and increasing physical activity had been conducted. Among the first systematic reviews of effectiveness of workplace intervention in reducing prolonged occupational sitting was by Chau et al. (2010). Chau and colleagues reviewed six studies with the primary and secondary aims were to increase physical activity and reduce sitting respectively. All studies used self-reported measures of sitting with only one study specifically assessed occupational sitting whereas the rest measured general sitting time. Samples size ranging from 66 to 2,121 participants and among middle aged staff recruited from universities and a number of selected companies. Interventions involved either advice on personalized physical activity, physical activity counseling together with fitness tests, e-messaging on physical activity and healthy eating or walking exercise. Majority of the studies reported non-significant reduction in sitting time including the only study that specifically measured sitting at work. The later also found no difference between weekdays sitting time in comparison with the control group. Chau and colleagues concluded that more evidence is needed to claim that workplace interventions are effective in reducing sitting time (Chau et al., 2010).

Inconsistent findings were reported by Shrestha et al. (2018) after reviewing 34 studies on interventions at work involving physical activity, workplace policy, effects of information and counseling as well as effectiveness of multicomponent intervention. These studies were conducted in high income countries with total of more than 3,000 participants. The findings showed that there was a reduction during intervention towards sitting time when using sit-stand desks with or without information and counseling but inconsistent effects reported for active workstations. No significant difference was observed on sitting time at work after employing walking policies at short and medium term follow up. However, occupational sitting was reduced on average by 40 minutes.day^{-1} by incorporating short breaks up to two minutes half hourly when compared to the long breaks. Significant decrease of sitting time was found at medium term follow up when computer prompts with information were used but no change at short term follow up. Similarly, findings for multicomponent interventions were also mixed. Majority of the findings were from the low quality evidences could be due to the small sample size and study design. These studies did not mention on the effects of the intervention over a longer period of follow up (Shrestha et al., 2018).

In contrast, Chu et al. (2016) showed consistent evidence of effectiveness of workplace intervention when conducted among white collar employees that bound to desk jobs. The systematic review involving 26 studies with total of 4568 employees showed pooled intervention effect towards reduction in occupational sitting by 39.6 minutes throughout eight-hour working period. Multicomponent intervention involving sit-stand workstation in combination with health education showed utmost significant occupational sitting by 90 minutes followed by sit-stand or active workstation alone by 73 minutes. Most of the studies were rated to be good to high quality and reported strong and consistent evidence of significant reduction in sitting at work.

1.5.5 Effects of interrupted sitting at work

Sedentary behaviour involves uninterrupted prolonged sitting especially among employees throughout their working period. In order to combat long sedentary bouts, frequent breaks were introduced. Various studies have reported the efficiency of sedentary breaks in reducing sedentary time among workers by using sit-stand workstation (Alkhajah et al., 2012; Gilson et al., 2012; Healy et al., 2013; Mansoubi et al., 2016; Pronk et al., 2012), treadmill installation (Ben-Ner et al., 2014; Koepp et al., 2013) and a pedalling device under the desk (Carr et al., 2012). Increased physical activity and energy expenditure were also reported (Ben-Ner et al., 2014; Levine & Miller, 2007). In agreement, systematic interrupted sitting with activities like walking at normal pace for five minutes after every 30 minutes of sedentary time has been demonstrated to additionally increase energy expenditure by up to 37%; such a change may help in controlling weight (Swartz, Squires, & Strath, 2011).

Sit-stand workstations were also shown to improve musculoskeletal discomfort especially on the upper body region and increase staff productivity (Hedge & Ray, 2004; Karlqvist, 1998; Pronk, Katz, Lowry, & Payfer, 2012) and reduce body fat percentage (Danquah et al., 2016). Improvement in high density lipoprotein cholesterol (Alkhajah et al., 2012) and total cholesterol (Graves, Murphy, Shepherd, Cabot, & Hopkins, 2015) were also observed after three months and eight weeks of intervention respectively. Besides low activity of alternate sitting and standing while working, walking on treadmill that fitted into the office desk was also introduced. Significant reduction in waist circumference, low density lipoprotein cholesterol and total cholesterol were reported after nine months intervention (John et al., 2011). Additionally, walking on treadmill at 1.6 $km.hr^{-1}$ while performing office tasks resulted in increased metabolic rate (Cox et al., 2011).

Thus, repeated breaks throughout sedentary time either by standing or walking, will increase energy expenditure than the sedentary state and may reduce the risk of cardiovascular and metabolic disorders (Healy et al., 2008).

1.5.6 Conclusion

To conclude, multiple approaches, in particular aiming at sedentary office workers, must be taken into account by employers to reduce occupational sitting and increase physical activity at work. As sedentary behaviour has been shown to be related to various health problems and can cause an economic burden for the company (Myers, 2008), practical layout of a workplace integrated with minimizing stationary sitting activity throughout working hours is a requirement for a healthy worker. Small steps like placing the printer or photocopy machines farther away from staff desks will promote standing and walking, and thus, interrupt sitting. The company could also introduce systematic short breaks depending on the department, and other suitable criteria to allow workers to reduce screen time and replace it with energy usage. Active work stations such as sit-to-stand or treadmill desks would allow more active screen time for employees who work with computers. Continuous motivation via health posters and desktop software might enhance the awareness about the importance of physical activity during working hours (Shrestha et al., 2016).

1.6 Stair climbing

Stair climbing is a vigorous physical activity which requires energy expenditure of 9.6 METs in the field (Teh & Aziz, 2002). As recommended by U.S. Department of Health and Human Sevices (2009), every adult should engage in moderate to vigorous types of activity for 30 minutes at least for five days in a week. Thus, stair climbing can contribute to increase physical activity to reach the weekly requirement in order to combat physically inactive lifestyle and gain health benefits.

Stairs are found regularly in the built environment especially in office buildings as well as shopping malls, train stations and health settings. Other advantages of stairs; 1) easy access and reachable by public, 2) free and always available, 3) can be easily integrated with daily routine to increase physical activity, and 4) does not require special skills or training to perform stair climbing. Thus, the excuses to avoid physical activity such as time constraint (Brownson, Baker, Housemann, Brennan, & Bacak, 2001) and difficult to exercise (Sallis & Hovell, 1990) do not apply to stair use.

1.6.1 Health benefits of stair climbing

One of the earliest study assessing on the benefit of regular stair climbing was by Fardy & Ilmarinen (1975). The 12-week stair climbing intervention with 15 participants recruited among healthy men to be in the experimental group. Participants were asked to climb 25 floors.day^{-1} and VO_2max was reported to improve by 10% post intervention. Similarly, VO_2max was reported to increase by 15% after 10 weeks of regular stair climb of 30 floors.day^{-1} in sedentary males (Ilmarinen et al., 1978). Ilmarinen et al. (1979) also tested the feasibility of stair climbing at work with participants who were among female employees. The intervention was divided into two groups, 12-week (n = 59) and 24-week (n = 26). Mean climb was of 65 floors.week^{-1} with two to four bouts.day^{-1} that each bout lasted one minute. Participants climbed at 70% of VO_2max. Greater reduction of rated perceived exertion (RPE) and skinfold were seen at the end of 24-week compared to the 12-week intervention. Significant decrease of body weight after 24th week was also observed.

In 1994, Loy et al. conducted a 12-week intervention in middle aged women to test on the differences between: 1) participants with external load, and 2) participants without external load. For the first group, participants spent 35 minutes on a stair climber device at 80 - 85% maximum heart rate for four days in a week. For the group with load, starting at the fourth week, external load was added which accounted for about 4% from their body weight and increased to 8% from week seven to week 12. Post intervention showed increased in VO_2max in both groups, without load and with load by 9.6% and 11.1% respectively (Loy et al., 1994). In 2007, Kennedy et al. recruited 29 office employees to climb eight flights of stairs which involved 145 steps that was accumulated in short bouts. The intensity was set at 75 steps.min^{-1} with one bout.day^{-1} in the first week and only performed during weekdays. In week three, the bout was increased into two bouts.day^{-1} and maintained with three bouts.day^{-1} from week five onwards. Significant improvement in fitness was observed.

Stair climbing also gives other health benefits besides increases fitness. In a study by Boreham, Wallace, & Nevill (2000), a total of 12 healthy but sedentary young females climbed one ascent.day^{-1} in the first week of intervention and progressed to six ascents.day^{-1} in week six and seven. One complete ascent involved 199 steps and took two minutes. Findings revealed improvement in lipid profiles with increased HDL-C and reduced TC/HDL-C ratio after seven-week intervention. Using a similar target group with the same staircase, Boreham et al. (2005) reported that with only five ascents.day^{-1} in week seven and eight at 90 steps.min^{-1} not only improved VO_2max by 17% but also reduce LDL-C by 7.7%.

A promotional campaign to increase stair climbing among sedentary employees was held for 12 weeks and six months in a public hospital. The campaign used posters as point-of-choice prompt and floor stickers to promote stair usage. Assessment after 12 weeks showed increased fitness and reduced in waist circumference, fat mass, diastolic blood pressure and LDL-C. The effects were persistent after six months of campaign (Meyer et al., 2010).

Another approach by Andersen et al. (2013) using email contained motivational message to the sedentary office employees in Copenhagen. Employees were encouraged to use stairs for 10 minute bouts.day^{-1} in groups who climbed together. At 10 weeks follow-up, there was an increase in aerobic fitness and decrease in blood pressure.

As stair climbing is categorized as a vigorous physical activity, it has been reasoned that seven minutes of time spent climbing the stairs daily would reduce 62% deaths from CHD (Yu, Yarnell, Sweetnam, & Murray, 2003). Additionally, a total of less than 30 minutes per week of stair climbing was adequate to improve cardiovascular fitness (Kennedy et al., 2007) and with minimum of 13 floors climbed daily could produce positive health effects (Ilmarinen et al., 1979).

1.6.2 Stair climbing intervention in public access settings

Stair climbing intervention in the shopping mall and public transit have shown to increase stair climbing by 6% (Webb, Eves, & Kerr, 2011) and 6.6% (Olander, Eves, & Puig-Ribera, 2008) respectively. The materials used for the intervention in the public access settings usually involved posters, banners, and stair risers.

1.6.2.1 Factors influencing stair climbing in public access setting

Factors that could influence effectiveness of the intervention using poster as a point-of-choice prompt were type of message displayed on the poster, poster size and its placement to assure visibility to the pedestrians. Kerr, Eves, & Carroll (2001) conducted four observational studies testing on the effects of different poster size, message contents and placement of the posters. The first study was completed in a shopping mall whereby A3 poster size was used and stair usage was observed for two weeks. The second intervention was also held in a shopping mall testing on three different sizes of posters: A3, A2 and A1. Each poster was affixed for two weeks. The third and fourth studies were conducted in a train station and shopping mall respectively and used the same two posters that displayed different messages, a) *‘Stay healthy, use the stairs’*, and b) *‘Stay healthy, save time, use the stairs’*. Effects of each poster were observed for two weeks. Results showed that stair usage was greater for A1 (4.7%) and A2 (3.9%) posters with no difference found for A3 sized poster compared to the baseline. Both displayed messages increased stair climbing by the pedestrians and shoppers but less effect was seen for the *‘Stay healthy, save time, use the stairs’* content on women in the shopping mall. However, the same message improved stair usage by 21% and 12% in men and women respectively at the Scottish commuter station during the 16 weeks intervention (Blamey, Mutrie, & Tom, 1995). Further, Boen, Maurissen, & Opdenacker (2010) tested the effectiveness of an A1 sized poster with a single message in promoting the use of stairs in shopping mall and two train stations. The poster displayed message read *‘Stay in form, take the stairs’* was placed between stairs and escalators throughout the four-day intervention period. Results showed that stair usage in the shopping mall had increased to 12% and similar outcome was also seen for the first and second train station with 8.6% and 18% respectively. Additionally, an A1 sized poster containing the message read *‘Take the stairs and stay healthy’* was used as a point-of-choice and placed at the platform entrance at two train stations in Copenhagen for one week. Stair use increased by 1/3 at both stations during and one week after intervention.

In terms of the content of the poster, a 12-week observation of stair usage in a shopping centre by Andersen, Franckowiak, Snyder, Bartlett, & Fontaine (1998) revealed that the posters used as a point-of-choice prompt between escalator and stairs increased by 6.9% for poster with health benefit content and 7.2% for weight control content. In agreement, Webb & Eves (2007a) conducted a 13-week observation on stair use in a UK shopping mall. Poster as a point-of-choice prompt with health promotion message was displayed at the intervention site and improved stair use by 161%. Surprisingly, the health promotion message (*'Stay healthy, save time, use the stairs')* was reported to be equivalently effective among high and low socioeconomic status in a four-week intervention at the underground train station in Glasgow (Ryan, Lyon, Webb, Eves, & Ryan, 2011). Poster with deterrent sign ('*Please limit escalator use to staff and those unable to use the stairs'*) used as a point-of-choice prompt in the airport also improved stair climbing by 14.4% (Russell & Hutchinson, 2000). Besides that, a cultural sensitive sign was used in a commuter setting to promote stair use in an eight-week intervention. The sign displayed an image of an African American woman with caption *'No time for exercise? Try the stairs!'* displayed next to escalator/stairs. Stair use was reported to increase by 16.4% among the African American group, with the greatest effect was observed among women (Andersen et al., 2006).

The simplicity of the message displayed has shown to encourage stair climbing. Lewis & Eves (2012a) tested potential effects of message complexity to promote the stair use in a UK train station. Two different types of messages were displayed in separate A1 sized posters, i.e. simple and complex messages. Poster with simple message was found to be more effective than the complex message in promoting stair usage, especially during the peak periods.

Similarly, the use of banners affixed to the stair risers in the shopping mall with the same eight simple message banners read *'Keep fit'* were found to have similar effect on stair use in comparison with eight banners with different messages (Webb & Eves, 2005).

Visibility is a very important factor for point-of-choice prompt poster and stair risers. Eves, Olander, Nicoll, Puig-Ribera, & Griffin (2009) used a stair riser banner that was affixed three metres above the ground with clear black letters and yellow background to assure visibility to the pedestrians. The banner consisted of three messages arranged in four lines, *'Take the stairs. Stair climbing burns more calories per minute than jogging. Burn some today'*. After three and half weeks of intervention, the platform with the largest area of visibility of the stair riser banner reported greatest effect of stair climbing. In agreement, Webb & Eves (2005) found that banners affixed to the stair risers in the shopping mall were more visible to the pedestrians due to the attractive design compared to posters. However, attractive design alone was not effective in promoting stair climbing. Adding a health promotion message increased stair use by 190% showing that the content of message is crucial to assure effectiveness of the stair climbing intervention (Webb & Eves, 2007b).

Multicomponent approach during intervention resulted in a greater impact towards stair use. Olander et al. (2008) tested stair riser banners at a UK train station in 2006 to 2007. The banners, '*Stair climbing burns more calories per minute than jogging. Take the stairs.',* were placed for 10.5 weeks and A1 sized posters was added with the same message as a point of choice prompt at the base of the staircases for further three weeks. Stair climbing was shown to increase when both stair risers and posters displayed at the same time even though stair use decreased during the peak hour with high volume of travellers. An observational study by Lewis & Eves (2011) displayed poster with message read *'Regular stair climbing helps prevent weight gain'* for two weeks and followed by another poster read *'Well done stair climbers! You have just burnt a 16th of the calories needed to avoid weight gain'* for further six weeks. Stair climbing was seen to increase specifically among overweight travellers. The use of a volitional message as a point-of-choice prompt adjacent to the staircases with motivational message displayed at top of stairs showed significant increase in stair use in the UK tram station. Higher stair climbing activity was reported among males, during early morning and high traffic volume (Lewis & Eves, 2012b).

1.6.3 Stair climbing intervention at work

An escalator is often the alternative to stairs in public access settings such as stations where at work, the choice is between stairs and lifts. The median baseline of stair use at work was found to be higher (35.7%) than in both shopping malls and public transit (5.4%) (Eves & Webb, 2006) as lifts are not always available (Nicoll & Zimring, 2009) and waiting time encourages stair use (Kerr, Eves, & Carroll, 2001a). Various interventions at worksite reported less effect on stair climbing when compared to the public access setting (Eves & Webb, 2006; Nocon, Müller-Riemenschneider, Nitzschke, & Willich, 2010). However, as stated in the report by Stanner (2004), the workplace is a platform for the employees to exercise and climb stairs in between breaks to get active. Hence, various worksite campaigns in promoting stair use were held with the most common approach was installation of a point-of-choice prompt poster at the intervention site.

1.6.3.1 Point-of-choice prompt to encourage stair use at work

Kwak, Kremers, van Baak, & Brug (2007) observed the effects of a point-of-choice prompt to promote stair climbing among blue and white collar workers. The three-week intervention used an A5 sized poster placed at the lift's entrance and A2 sized poster displayed in the stairwell. All posters were designed with green colour background with black text. There were four different messages for A5 sized posters, 1) *'Free workout?'*, 2) *'Walking buffet?'*, 3) *'A break?'*, and 4*) 'Desert?'* whereas A2 sized posters displayed two different messages read *'One step closer to your energy balance'* and '*On your way to the balance between food intake and physical activity'* with both messages ended with *'The stairs. A good idea!'.* Stair use was reported to increase by 4.4% and 2.6% for blue and white collar respectively even though white collar employees used the stairs more and female employees were found to be more affected than male workers.

A point-of-choice prompt containing health message was used by Auweele, Boen, Schapendonk, & Dornez (2005) in a five-storey administrative building. The two-week intervention involved a poster that read *'Fit and healthy. I take the stairs'*. Stair climbing increased from 69% during baseline to 77% during intervention. Additionally, stair use was also seen to improve by using a message based on caloric expenditure (Dorresteijn, van der Graaf, Zheng, Spiering, & Visseren, 2013). A poster with the message, *'Stair climbing increases energy expenditure by 11-fold',* was placed on the lift's door to be seen by employees and visitors at the University Medical Centre. After two weeks, findings yielded stair use increased by 11.2%. Similarly, point-of-choice prompt using caloric expenditure content increased stair climbing at the intervention site when compared to the stand at a health information day. Olander & Eves (2011) compared the effectiveness of a stand containing stair climbing benefits and point-of-choice prompt poster in two separate interventions held at four buildings in a university campus. The first intervention was performed on the Workplace Wellbeing Day and continued for further five days. A yellow A2 sized poster was used with message read *'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 four days worth of food'* accompanied with leaflets disseminated to the visitors with information on the benefits of stair climbing that stairs are always available, burns more calories per minute than jogging and improves fitness and health. The second intervention used the same message and positioned in between the lift and stairs as a point-of-choice prompt. Together, an A4 sized poster read *'Stair climbing always burns calories'* was displayed next to the lift button with a yellow arrow showing the direction of the stairs. Findings revealed that there was no effect of the poster compared to the baseline, whereas point-of-choice prompt poster improved stair use by 4.7%.

1.6.3.2 Multicomponent intervention at work

A year later, a similar study was replicated by Eves, Webb, Griffin, & Chambers (2012) but with several modifications. Multi-component stair climbing campaign was held at two different worksites with predominantly white collar workers. The first intervention was held at the five-storey City Council Building which involved an A2 sized poster displaying similar message and arrow as used by Olander & Eves (2011). The second intervention used a multi-component approach of poster and stairwell messages and was held at a four-storey Water Supply company. The same poster as in the first worksite was used but with additional six different messages targeting weight control, caloric expenditure and stair climbing as a daily exercise affixed to the wall besides the stair risers between each floor. This three-week intervention revealed that at the worksite which involved poster and stairwell messages, greater effect of stair climbing was observed compared to the site with poster alone. Nonetheless, Adams & White (2002) conducted a four-week intervention among staff, students and visitors to promote stair climbing in a seven-storey university building. Four signs targeting health (*'Using the steps is quicker, healthier, and burns more calories'*), calories (*'Climbing the stairs burns 5 times as many calories as standing in the lift'*), speed (*'This lift can take up to 50% longer than climbing the stairs'*) and lifestyle (*'Time to take some exercise?'*) were used. The first three signs were placed adjacent to the lift's door and one sign inside the lift while the fourth sign was affixed to the wall within the stairwell. There was no improvement in stair use compared to the baseline.

Multifaceted interventions have shown different outcomes towards stair use. Boutelle, Jeffery, Murray, & Schmitz (2001) performed an eight-week intervention in an eight-storey university building. The first four weeks used a sign as point-of-choice prompt, read *'Take the stairs for your health'* placed between the stair and lift and the following four weeks added artwork and music in the stairwell. There was no improvement on stair climbing when using the sign alone but stair use increased after adding artwork and music in the stairwell from 11.1% at baseline to 15.5% during intervention. An e-mail was sent a week after introduction of a point-of-choice prompt from a medical doctor and seemed to be effective. An email advising on the benefits of stair climbing towards health that was sent to all employees showed improvement in stair use by 16% (Auweele et al., 2005). Additionally, placement of posters with different messages at few areas at the intervention site increased stair use as shown in a six-week campaign in a five-storey office building (Eves, Oliver, & Mutrie, 2006). An A2 sized poster read *'Doctors have found that 7 minutes of stair climbing a day halves your risk of a heart attack over a 10-year period. There are 1440 minutes in a day. Can you spare 7 minutes to live longer?'* was placed in the lobby and at the top of each flight whereas the A4 sized poster was displayed inside the lift (*'7 minutes of stair climbing a day protects your heart'*). Six other posters with different messages; *'Regular stair climbing aids weight loss', 'Regular stair climbing burns more calories per minute than jogging', 'Regular stair climbing is free exercise', 'Regular stair climbing lowers cholesterol', 'Regular stair climbing keeps you fit',* and *'Regular stair climbing provides daily exercise'* were positioned on the stair risers for each flight of stairs. Findings revealed that stair descent was more common than ascent and the campaign showed greater effects on overweight employees. In agreement, different motivational messages displayed during the stair climbing intervention at work could improve stair use. Nomura, Katayama, Kashiwa, Akezaki, & Sato (2014) conducted a long term campaign on stair climbing involving public service workers at the Kochi Prefectural Office in Japan. The placement of 48 different posters on the stair risers acted as motivational signs to promote stair use and posters were replaced irregularly in between one to three months. The intervention started in August 2007 till February 2009 and findings revealed increments of stair use among female and male workers from 31.5% to 58% and 26.3% at baseline and 62.4% during intervention respectively.

1.6.3.3 Effectiveness of stair climbing intervention at work

Despite that, a number of interventions showed no significant changes towards stair use. For instance, Eves, Olander, Webb, Griffin, & Chambers (2012) conducted an Everest Campaign for 18 days in a 12-storey office building. The green A2 sized poster with message read *'Take the stairs to the top of this building once a day and in a year, you would have climbed Mount Everest almost twice. Now that's a lot of exercise'* was affixed at every floor in the stairwell as point-of-choice prompt. Another poster, yellow A4 sized poster with content read *'Take the stairs to Everest'* was placed next to the lift button together with a yellow arrow stating *'Stairs this way'*. The same A4 poster was also displayed in the lift. There was no effect of posters on stair climbing even though the content of the A2 poster was claimed to be the most motivating content from the field interview. Additionally, the use of a point-of-choice prompt poster read, *'Improve your health and fitness one step at a time…use the stairs'* placed at the health care facility in between stairs and lift produced only small effects on stair use. Re-introduction of the poster after another two weeks, revealed that the point-of-choice prompt did not sustain stair use during second intervention and after removal of the poster (Marshall, Bauman, Patch, Wilson, & Chen, 2002). Kerr et al. (2001a) claimed that employees were willing to climb on average maximum of 3.5 flights of stairs only. The first intervention involved a nine-storey building which used an A1 sized poster read *'Stay healthy, use the stairs'* placed at the lift's entrance and adjacent to the staircase. The two-week observation revealed that there was no effect of poster towards stair climbing even though stair descent was significantly increased during intervention. Stair use was found to be more common among females and stair avoidance was higher when the crowd opted for lift as a choice of a person could attract the whole group to use the lift (Adams et al., 2006).

In the second intervention, observations were made for four weeks at another worksite, an accountancy firm with four flights of stairs. Similar findings were reported with no improvement on stair use, but males used stairs more than females, and stairs were often avoided when carrying load. The barriers that discourage the use of stairs were office level, time, load and habit of laziness (Kerr et al., 2001a).

1.6.3.4 Factors influencing stair use at work

The findings from a semi structured interview reported factors that influenced stair use were; 1) direction of travel (ascent or descent), 2) distance travelled, and 3) journey time. Stair climbing was preferable when it involved not more than four flights of stairs and when not in hurry. The reasons for choosing the lifts were the availability of the lift, to avoid sweating, too lazy to climb stairs, and too high to climb (five flights and more) (Adams & White, 2002). The immediate availability of the lift enhances avoidance of stairs. In times where one of the lift is out of order, the demand of the lift increases and prolongs waiting time. Consequently, stair use becomes an option even though stair descent was found to be more common than ascent (Olander & Eves, 2011b). Reducing the convenience of the lift and its accessibility would probably increase stair use at work. Nonetheless, design of the built environment influences stair use among employees (Bungum, Meacham, & Truax, 2007).

1.7 Habit for stair climbing and sitting

Much of the behaviour is purposive and influenced by planning (Ajzen, 1991; Orbell & Sheeran, 1998; Sheeran, 2002). Nonetheless, when behaviour occurs repeatedly in the same situation, it is often called a habit and both good and bad habits can influence health. Seminal research on habits contrasted thoughtful deliberation involved in planning behaviour when a new situation was encountered with more automatic processing with repetition of the same situation (Ouellette & Wood, 1998; Verplanken & Aarts, 1999). A successful previous choice in the same situation will encourage its repetition (Verplanken & Aarts, 1999) and reinforcement of any choice by success inevitably reinforces the contextual cues associated with that option. Subsequent encounters with the cues may prompt the behaviour in a relatively automatic manner (Aarts, 2007; Danner, Aarts, & De Vries, 2008; Gardner, Abraham, Lally, & de Bruijn, 2012; Lally, Van Jaarsveld, Potts, & Wardle, 2010; Orbell & Verplanken, 2010).

Habits can be operationalized as impulses to action triggered by contextual cues that have been associated with behavioural choices that succeed in their goal (Aarts, Paulussen, & Schaalma, 1997; Benjamin Gardner, 2015; Ouellette & Wood, 1998; Verplanken & Aarts, 1999; Verplanken, Aarts, & VanKnippenberg, 1997; Wood & Neal, 2007). Concerning sedentary behaviour and stair climbing, both behaviours are linked to energetic costs. Sitting cost less than standing and choosing a lift or an escalator to ascend costs less than climbing the stairs. For choice between stairs and an escalator, the lower energetic cost of the escalator reinforces its choice so that it can become habitual (Kerr, Eves, & Carroll, 2001b; Webb & Eves, 2007b). The cues to which escalator choice is linked are the presence of an available escalator. For sitting, however, the situation may be different. The cues for sitting are task related, e.g. a desk with a computer, and sitting occurs to meet the higher order goal of the task. Often individuals are unaware that they are sitting, reporting that it occurs as part of a task (Martínez-Ramos et al., 2015). Thus, workplace sitting may be a relatively non-conscious, routine behaviour that facilitates the over-arching goal of the work. As such it may become a relatively habitual response that is linked to the work context (Gardner, 2015).

Central to this theorising about habits, is the automaticity of response to contextual cues. In the only experimental study of habit development, Lally and co-workers asked individuals to adopt new health behaviour, e.g. drinking a glass of water, which would be linked to a self-selected, daily cue, e.g. eating breakfast. The participants reported daily whether the behaviour occurred and how automatic it felt to perform. Lally and co-workers modelled the potential development of automaticity over days, with evidence of reaching an asymptotic maximum in self-reported automaticity reflecting development of habitual responses to the cue. Eating, drinking and physical activities were the new behaviours chosen by the participants. Development of habitual processes in the exercise group (median = 91 days, range 18 - 265 days) 'took one and a half times longer' (Lally et al., 2010) than development of eating or drinking habits. It is possible that physical activity such as going for walk after breakfast was a more complex behaviour than drinking a glass of water.

The type of physical activity may influence the level of automaticity in that a simple form of behaviour may be associated with increases in the potential level of automaticity in response to a cue (Verplanken, 2006). Stair climbing in response to a cue is a relatively simple physical activity. A six-month quasi-experimental study promoting stair use with point-of-choice prompts in a UK shopping mall reported increased stair climbing during the intervention. Importantly, stair climbing was higher than baseline after the second and eighth week of removal of the stair riser banners (Kerr et al., 2001b)**;** with similar results five weeks and 12 weeks after removal in Webb & Eves (2007b) and Blamey et al. (1995) respectively. Clearly, the behaviour can outlast the presence of the health promotion cue. Stair climbing interventions with point-of-choice prompts could encourage pedestrians to repetitively climb the stairs and potentially facilitate a habit of stair use (Verplanken & Melkevik, 2008); the reinforcing stimulus would be the achievement of a successful health enhancing behaviour. Even if a pedestrian had missed some of the bouts of stair climbing in response to the prompt, it may not interrupt habit formation (Gardner & Lally, 2013).

Consistent with Lally and co-workers study, most research on automaticity has typically employed a self-reported measure (Gardner & Lally, 2013; Verplanken & Orbell, 2003). Recently, Phillips & Gardner (2016) have argued that it is the initiation of a behaviour which is the key to changing habits. They distinguished initiation of behaviour from the different components required to execute the behaviour. For example, cycling to work requires a number of different components to execute the entire journey whereas initiating the journey requires getting the bike and starting to cycle. Gardner (2015) argues that the initiation of an event in response to a cue is the most likely place where habits can change. Phillips & Gardner (2016) modified the self-report habit index (SRBAI; Gardner et al., 2012) so that it reflected either initiation of physical activity or execution. Only the instigation component of automaticity predicted physical activity frequency in daily diary reports over a one-month period.

1.8 Purpose of the current thesis

This thesis consists of three interventions in promoting the use of stairs as opposed to lifts and investigating health outcomes with regards to the regular stair climbing activity. The first intervention was performed in a student residence. The main objective for this intervention was to test for reduction in electricity usage by promoting the use of stairs instead of lifts among the students. Posters pertaining to weight loss depending on building's height were placed adjacent to the lifts and acted as point-of-choice prompts by the lift button.

The second intervention focused on combating the sedentary behaviour among office workers. In this feasibility study, scheduled stair climbing activity was followed by participants throughout their working hours consistently for eight weeks. Individuals were prompted to climb four floors eight times a day following a brief message displayed on their office computer. The aim was to interrupt sitting with stair climbing to shorten employees' sedentary bouts. The effects of stair climbing activity consecutively for two months were analysed to see the implications of this planned activity on lipid profiles and fasting glucose level.

The final laboratory intervention project assessed the outcomes on health markers of continuous sitting compared with interruption to sitting of walking or stair climbing. Participants were tested for the three activities on a single day separately, given a week break in between for the wash out period to take place. Every session took eight hours in the laboratory and these activities were constructed based on the intensity: no activity (sedentary), light intensity walking and vigorous activity of stair climbing. A mixed of carbohydrate and fat beverages were consumed after three hours. The measurement of health outcomes was similar to those in the second intervention. Effects on postprandial triglycerides and glucose were assessed for the three conditions.

The findings of these interventions were hoped to be a stepping stone for future research to investigate the therapeutic amount of stair climbing activity that can optimise health and reduce the economic burden causing by cardio-metabolic risk factors.

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CHAPTER 2

ENERGY CONSUMPTION BY LIFTS: CAN HEALTH PROMOTION OF STAIR USE REDUCE ELECTRICITY BILLS FOR BUSINESS?

2.1 Abstract

Lifts are almost ubiquitous in modern, high rise workplaces. The greater the number of lifts available in a building, the more likely it is that they will be used. Thus, lifts will increase the energy burden, and economic costs, of a building. This study tested the effectiveness of health messages displayed on posters to promote stair use and reduce the use of the lifts, and consequently their cost among first year students. The overall aim of this research was to promote stair use for health as an intervention that would reduce electricity consumption for business. There were six buildings at Mason Hall, accommodation for University of Birmingham students which comprised buildings of three storeys (n = 2), four storeys (n = 4) and five and solitary six storey buildings (n = 5), with 11 lifts and 15 stair cases available for use. Posters with a message based on the potential calorific expenditure from a single total ascent were displayed for four weeks. The interventions were performed during two terms, autumn and spring, involving two different group of first year students to assess potential habit development towards stair use. The energy cost of the lifts was monitored throughout the study. Results showed no significant difference in electricity consumption between baseline and intervention, for either intervention period (p= .799). These data provide no evidence that health-based stair use interventions in student residences can reduce the electricity consumption of the lifts.

Keywords: stair use, lifts, electricity consumption, health promotion posters, point-of-choice prompts

2.2 Background

Physical well-being can be achieved by engaging in physical activities, endurance training as well as having a balanced dietary intake (Hong & Peltzer, 2017). Recommended guidelines for adults to gain sufficient health benefits is to perform moderate to vigorous intensity activity for 30 minutes per day for at least five days per week, in bouts of 10 minutes or more (Tremblay et al., 2011). Moderate to vigorous physical activities require 5 or more METs of energy expenditure, i.e. 5 times higher than the energy costs while resting. Activities such as brisk walking, cycling and playing outdoor games have been reported to meet the intensity requirements (Strong et al., 2005). Stair climbing is a vigorous lifestyle physical activity due to the need to raise weight against gravity; typically, it requires more energy per minute than jogging (Ainsworth et al., 1993). In the field, Teh & Aziz (2002) estimated the energy expenditure during stair ascent as 9.6 METs when participants climbed at their own chosen rate whereas, even at lower step rates of 70 steps.min^{-1}, Bassett et al. (1997) estimated climbing at 8.6 METs. In daily life, rather than in the laboratory, stair climbing is a vigorous physical activity that can be performed unplanned at anytime and anywhere without many constrictions for most of the population. Furthermore, stairs are found regularly in the workplace and public access settings such as train stations and shopping malls. Thus, stair climbing can be accumulated during working hours as well as during daily living such as when shopping or in travel contexts with few time constraints.

While stair climbing can reduce time costs of a journey at work, it is also beneficial for health. Increased stair climbing activity has been shown to improve cardiorespiratory fitness, lipid profiles and weight status in experimental (Allison et al., 2017; Boreham et al., 2005; Boreham, Wallace, & Nevill, 2000; Kennedy, Boreham, Murphy, Young, & Mutrie, 2007; Meyer et al., 2010), and been associated with reduced risk of strokes, heart attacks and osteoporosis in observational studies (Jakes et al., 2001; Lee & Paffenbarger, 1998; Paffenbarger et al., 1993; Paffenbarger, Hyde, Wing, & Hsieh, 1986). Thus, in accordance with the beneficial outcomes of increased stair climbing on health, numerous intervention programs have been conducted worldwide to increase stair climbing activity (Armstrong, Candeias, & Richards, 2005).

Most of these public health interventions were performed in worksites and public access settings such as train stations and shopping malls. Point-of-choice prompts were used as the strategy to encourage the public in choosing the method to reach their destination either by using the stairs rather than the lift or escalator. Simple posters detailing potential health benefits of stair climbing were located at the point-of-choice between lifts/escalators and stairs. These simple interventions have been shown to increase stair climbing, though less consistent effects are evident for worksites than for public access settings (Bellicha et al., 2015; Eves & Webb, 2006; Nocon et al., 2010). However, the effectiveness of the interventions have been reported to increase with additional components of the interventions that supplement the health prompt (Lewis & Eves, 2012; Eves, Webb, & Mutrie 2006). For example, use of extended messages in the stairwell that reinforce the main motivational messages in the poster have been employed (Eves et al., 2006; 2012). In another approach, when motivational posters at the point of choice were accompanied by aesthetic changes to the stairwell, more people used the stairs in a university building (van Nieuw-Amerongen, Kremers, de Vries, & Kok, 2011). A further strategy that may help to encourage the use of stairs by the population is by performing two phases of interventions. For example, some studies revealed that there was a significant increase of stair climbing activities during the second phase relative to the first (Lewis & Eves, 2011; Olander & Eves, 2011). In explanation, first exposure to the intervention functions as the introduction of a new potential physical activity and the second phase of the intervention may play a role in the development of a sustained habit of stair climbing (Bellicha et al., 2015, 2016).

Only one interesting intervention study to promote energy saving with stair climbing as health behaviour has been conducted previously. Houten, Nau, and Merrigan (1981) used posters with printed health messages in an attempt to reduce energy consumption of the lifts by encouraging the use of stairs in university buildings. While there were no effects of health messages in Houten and co-workers research, increases to the closing time of the lift reduced lift usage and energy. Office buildings generated about 10 to 20 times higher of electricity usage compared to the residential flats (Yang, Lam, & Tsang, 2008) and lifts accounted for about 5% of total electricity consumption of an office building (American Council for an Energy-Efficient Economy, 2017). Thus, interventions that reduce the electricity costs of the lifts by encouraging choice of the stairs, especially in business buildings, may be beneficial for business costs. If such an effect could be demonstrated, it might encourage businesses to adopt health promoting signage in their workplace.

This study aimed to promote the usage of stairs among students living in university accommodation with health promotion signage. The stair use interventions were conducted initially in the spring of 2015 and repeated in the autumn of the subsequent academic year. The target group involved were predominantly first year students from two different cohorts. The reason of having the intervention during two terms was to assess potential habit development towards stair use. The main aim was to reduce electricity consumption by encouraging use of the stairs instead of the lifts. Posters with health messages were displayed in each building. It has been argued that point-of-choice prompts interrupt established habits of escalator and lift use by encouraging deliberation about the behavioural choice (Kerr, Eves, & Carroll, 2001; Webb & Eves, 2007; Olander & Eves, 2011). This study used a quasi-experimental approach to test this premise. New habits develop when a consistent behavioural choice is rewarded in a consistently encountered context (Gardner, 2015; Gardner & Lally, 2013; Ouellette & Wood, 1998). For escalator and lift choice, the reward is reduced energy expenditure (Kerr et al., 2001). The residents were primarily first year students, i.e. relatively new to the context. Nonetheless, students in the spring term would have already experienced an autumn term, in which any habits for lift use in that context could develop. In contrast, the context would have been more novel for students in the first term in the residences, i.e.; the autumn term. As a result, we expected greater responsiveness to the intervention in the autumn term than the spring. Occupants in the autumn term would be less likely to have developed habitual patterns of lift usage than those in the spring term. The point-of-choice prompt would encourage occupants in the autumn term to make a behavioural choice to use the stairs. Thus, we predicted greater responsivity to the point-of-choice prompt in the autumn term than in the spring term. For signage, we hypothesized that posters about weight control would encourage the residents that increase in stair use would help target weight control, a meaningful goal for a student population. Any increase in stair use would be rewarded by progress towards that goal. We adapted a campaign that had previously been successful in public access setting (Lewis & Eves, 2011). We estimated the potential energy expenditure of a single climb to the top of each residence. We extrapolated this information, to the potential fat loss over a whole year; first year students would spend a year in the residences. Different heights of building allowed a test of the magnitude of potential fat loss as an encouragement to climb. Whereas those in a three-storey building could accumulate one pound of fat loss, those in a five-storey building could accumulate one and two thirds of a pound of fat loss. We expected that the greater potential benefit of the five-storey building would translate into greater responsiveness to the signage in the taller building. Nonetheless, the overarching aim was to use health promotion to reduce the usage of the lifts throughout the intervention periods and hence to produce electricity saving for business.

2.3 Methods

Study site

The study was conducted at Mason Hall, University of Birmingham, a student residence which comprised of six buildings with different heights of climb. The halls of residence were situated about 0.8 miles from the main university campus where academic sessions take place. These three to six storeys buildings provided flats, apartments as well as studios designed for primarily first year undergraduates and couples, with a few post graduate students who acted as wardens. There were eleven lifts, and a stairwell was located just opposite each of the lifts.

Study design

Two sizes of posters; A3 and A4, were used as a multi-component intervention to promote stair climbing. The A3 sized posters were placed on the notice board adjacent to the lift's door on the ground floor whereas the A4 sized posters were affixed onto the brick wall for the rest of the floors in each building by the staircases. Each poster displayed one message focussing on the amount of fat loss estimated when climbing the stairs daily for a year. The messages were adjusted based on the height of the climb at each stair/lift complex. The message for a three storey climb read, '*Stair climbing always burn calories. Did you know? If you've climbed to the top of this building, once each day, over a year that would burn 1lb of fat*' (Figure 2.1). The amount of fat loss differed depending on the number of stories for each climb. Based on the height of the climb, it was estimated to lose about 1 lb for a three-storey climb (n = 2), 1⅓ lb for a four-storey climb (n = 4) and at least 1⅔ lb for the five and the solitary six-storey climbs (n = 5). The posters were checked regularly and any missing posters were replaced immediately.

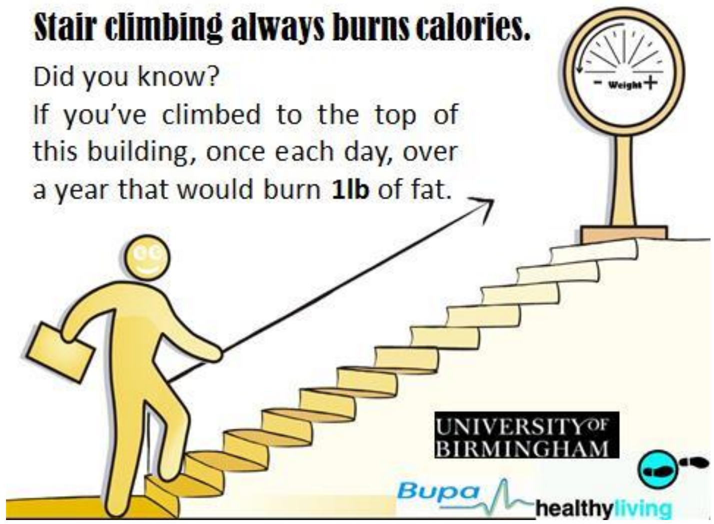

Figure 2.1 Poster used for intervention at Mason Hall.

The study was conducted during autumn and spring terms. The four-week intervention started from 9th of February until 8th of March 2015 for spring term time and in next year's autumn term from 2nd November to 6th December 2015. As a result, different populations of first year students were exposed to the intervention in the spring and autumn terms. The four-week baseline data was retrieved from the previous records of monthly energy usage data provided by the Head of Utilities, University of Birmingham. Energy consumption was measured as electricity usage for each lift in kilowatt hour (kWh) unit each half hour.

Ethical approval

As the study did not involve any individual participants but rather total electricity usage for each building, the chair of the ethics committee waived the need for full ethical approval.

Statistical analysis

Mixed between and within subjects repeated measure analysis of variance (ANOVA) was employed. The between subject factors were semester (spring vs. autumn), height of climb (3 vs. 4 vs. 5/6 storeys) and intervention (baseline vs. posters) and the within subject factor was time. The eighteen time points that were selected for analyses were those when students could have been expected to be using the lifts and stairs, with six time points with half an hour range in between for each morning (7:30am to 10:00am), afternoon (4:30pm to 7:00pm) and evening (7:30pm to 10:00pm). These were based on traffic for the residence; a) getting up in the morning, going to breakfast and then to the university, b) coming back from the university classes and other academic activities, and c) going out for dinner, going to the gym and meeting up with friends after academic sessions.

2.4 Results

Figure 2.2 below of the consumption over time in each semester illustrates the pattern of usage over the different time points. According to the trend of lift usage, there was a generally positive increase in lift usage throughout the day, peaking at 6:30 to 7:00pm after which it declined from early evening onwards. Within this general trend, there was an increase in the electricity consumption in the morning period. Nonetheless, the figure clearly shows that between 6:00 to 6:30pm the lift was in highest demand (Figure 2.2).

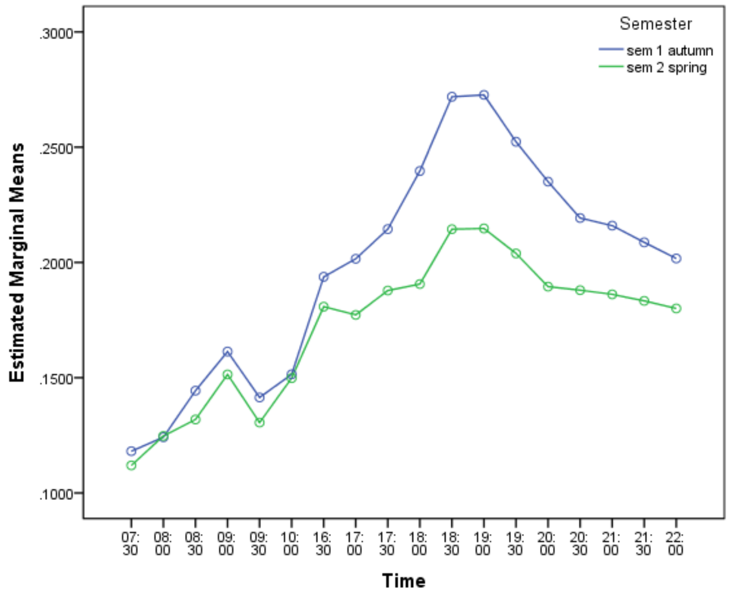

Figure 2.2 Estimated marginal means of electricity usage for both semesters; autumn and spring.

Inspection of Figure 2.2 also reveals that the significant interaction between semester and time reflects greater usage of the lift in the autumn term than in spring term in the period after students would have returned from the university after academic work (4:30pm onwards). We have no explanation of the difference of stair use during these two terms.

Mauchly's test indicated that the assumption of sphericity had been violated ($X^2(152) = 9730.2$, $p < .05$ for the repeated measures ANOVA. Therefore, the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .296$). Results for the within-subject factor of time with Greenhouse-Geisser correction, summarised in Table 2.1 below, revealed that a main effect of time interacted with the between subject factors of building height, and semester, with an interaction of all three as predictors of electricity consumptions ($p = .04$).

Table 2.1 Summary for the effects on electricity usage of the between and within subject factors.

Effect	**F**	***p* value**
Time	56.17	< .01
Time*Height	7.59	< .01*
Time*Baseline vs. Intervention	0.47	.80
Time*Semester	3.19	.01*
Time*Height*Baseline vs. Intervention	0.58	.83
Time*Height*Semester	1.89	.04*
Time*Baseline vs. Intervention*Semester	0.49	.78
Time*Height*Baseline vs. Intervention*Semester	0.37	.96

Despite some minor differences in usage during baseline and intervention periods over time, the figure does not indicate any differences as a result of intervention. This impression was confirmed in the analyses. There was no overall significant difference for electricity consumption during baseline and intervention periods ($F_{(1, 868)} = 0.03$, $p = .86$) nor a significant interaction over time ($F_{(5, 4372.8)} = 0.47$, $p = .80$). Additionally, there were also no significant interactions between baseline and intervention periods with the other factors of time, height of climb and semesters which would indicate any effects of the intervention on trends of electricity usage ($F_{(10, 4372.8)} = 0.37$, $p = .96$) as shown in Table 2.1. Figure 2.3 below summarises the effects of intervention on electricity usage.

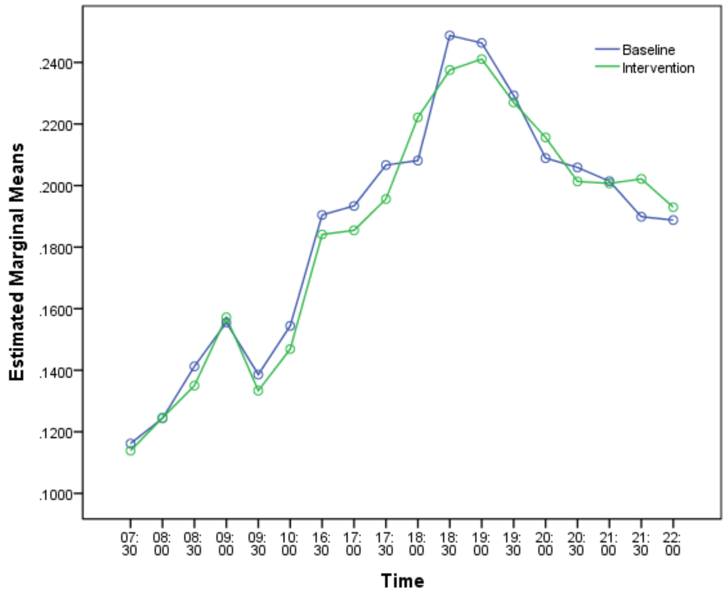

Figure 2.3 Estimated marginal means of electricity during baseline and intervention periods.

Table 2.2 below summarises the between subject effects in the analysis. Concerning the intervention, there was no significant difference between the effects of the intervention for height of climb ($F_{(2, 868)}$ = 0.10, p = .90) that would be consistent with differential effects of the message on the posters. Further, there was no significant difference between the effects of the intervention in the two semesters that would be consistent with greater effects in the autumn term when habits of usage were less well established than in the spring term ($F_{(1, 868)}$ = 0.24, p = .62).

Table 2.2 Effects of electricity usage between subject effects.

Effect	F	*p* value
Height	45.91	< .01
Baseline vs. Intervention	0.03	.86
Semester	7.35	.01*
Height*Baseline vs. Intervention	0.10	.90
Height*Semester	4.56	.01*
Baseline vs. Intervention*Semester	0.24	.62
Height*Baseline vs. Intervention*Semester	0.02	.98

Figure 2.4 below summarises the differential effects of time of the three posters and hence height of the climb that was involved at the different choice points (see Table 2.2). As can be seen, electricity usage was greatest at the four-storey climb and least for the three-storey climb. As with the effects of semester, we have no explanation of these differences between choice-points that represented different heights of climb. Note that as there were no interactions involving intervention, these effects are not attributable to differential effects of the posters but rather some unexplained difference between the choice-points.

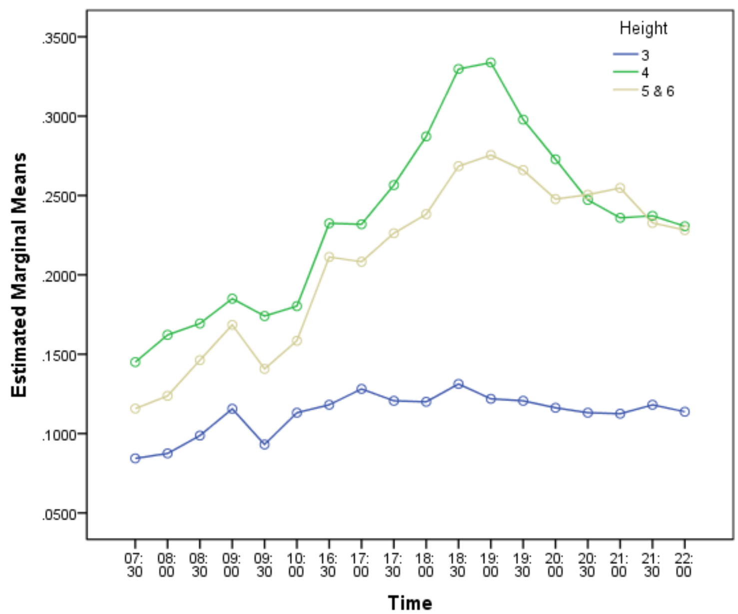

Figure 2.4 Estimated marginal means of electricity usage for height of climb (3, 4 and 5/6 storeys) over time.

2.5 Discussion

In summary, this study used simple and low cost posters in an attempt to influence the choice between choosing the lift or the stairs among the residents of university halls. Based on the results gathered from electricity consumption after the intervention, posters at the point-of-choice between stairs and lift did not improve stair usage in Mason Hall in either the spring or the autumn terms. The overall pattern of electricity consumption was for major increases after 4:30pm that peaked around 6:30pm whereas usage was lower during the morning period. Such a result suggests more ascending and descending traffic occurs after academic sessions at the university have been completed.

Electricity consumption by the lift includes journeys for both ascent and descent. Such a combined measure of lift usage, i.e. the converse of stair usage, typically provides stronger evidence of point-of-choice efficacy; stair usage is a variable more likely to change than the more specific measure of stair climbing (Eves & Webb, 2006; Bellicha et al., 2015). These data provide no evidence that weight control messages influenced first year student's behaviour when choosing between stairs and a lift at their residence. This failure to change behaviour means that the study was unable to test potential effects of habit development between autumn and spring terms or the different messages that were associated with different height buildings. As a result, all of the experimental hypotheses were rejected.

One possible explanation for the failure to change consumption could have been the message displayed on the posters. Despite emphasizing the amount of weight one could lose with daily stair climbing to the top floor of the building, it has failed to attract the residents to the stairs and away from the lift. Clearly, not every student who used the lift occupied rooms on the top floor, and hence might not have thought the message applied to them as they lived on a lower floor. Although previous studies recorded positive impacts of a weight control message on stair climbing in public access settings (Andersen, Franckowiak, Snyder, Bartlett, & Fontaine, 1998; Lewis & Eves, 2011) and workplaces (Eves, Olander, Webb, Griffin, & Chambers, 2012), these interventions targeted the general population and were not pretested for their potential efficacy with students. For first year university students, weight control may not be a major concern. Another possible reason for the failure is that students could have preferred to walk in groups back from the university. Pedestrian traffic at the choice-point between lifts and stairs reduces stair climbing (Eves et al., 2006; Olander & Eves, 2011; Eves et al., 2012). If one member of a group travelling together is unwilling to take the stairs, then the rest of the group could be constrained to use the lift, despite some having a positive view of the intervention. Further, lift usage increased at the end of the afternoon, following academic sessions. It is possible that a tiring day at university, coupled with the walk back from the campus, was a barrier to increase physical activity using the stairs.

Overall, there was more consumption for the lifts in the autumn term than in the spring term. One possible explanation for the finding was that this study performed two interventions whereby the first intervention was completed during the spring term in 2015 and followed by different cohort for second intervention during the autumn term of the same year. As a result, primarily different student populations of first years would have been targeted in the different terms of the study. The greater electricity usage in the autumn term overall may simply have reflected a population during that term that was less willing to climb stairs and preferred to use lifts. Alternatively, students in the autumn term may simply have made more journeys overall. A similar explanation may explain the differences between usage based on the height of climb. The lowest electricity consumption occurred for the least height of climb, three storeys, consistent with effects of potential height of climb on stair use (Eves & Webb, 2006; Lewis & Eves, 2012; Olander & Eves, 2011). Nonetheless, there was more consumption for the four-storey climb that the taller five and six-storey climbs. As height of climb was a between subject variable, different populations were exposed to the messages. Residents in the four-storey buildings may have been less willing to take the stairs than in the higher buildings or simply make more journeys entering and exiting the building as part of their daily life.

2.6 Strengths and weaknesses

This study focused on the impact of calorific expenditure message to promote stair use among first year university students. To date, there is no evidence found on the effect of this type of message on this target group. Previous studies conducted stair use interventions in university buildings but with different type of messages, and involved not only university students but also staff and visitors (Engelen, Gale, Chau, & Bauman, 2017; Grimstvedt et al., 2010; van Niew-Amerongen et al., 2011). This study involved 11 lifts to assess stair use in different height of buildings. Such number of lifts could attribute to differential effects of posters towards stair use. Furthermore, the intervention was performed twice to compare the effects of choice-of-prompts as well as to assess any habit development towards stair use.

This study used electricity consumption of the lifts as a potential proxy for stair usage; a previous study had reported changes in observed lift usage and electricity consumption at a university site (van Houten et al., 1981). Nonetheless, most of the electricity consumption of lifts occurs when they are not in use; maintenance of readiness for use is the most common state. In addition, electricity consumption occurs for both ascent and descent whereas the intervention targeted stair use. It is possible that electricity usage was an imperfect proxy for stair use. Typically, effects of climbing interventions are relatively modest; most journeys use the mechanised alternative. It is possible that any small change in behaviour was masked by overall usage and the dependent measure was insensitive to change. Further, the variable of interest is the proportion of journeys that use the stairs instead of the lift. Energy costs of the lift alone cannot provide information about the percentage of ascent using stairs. Apart from that, this study only assessed on the electricity usage whereas additional information of stair users such as direction of stair use (ascent or descent), total number of students that used the stairs, gender and also weight status were not evaluated during the intervention.

In analyses, the between subject factor of intervention would have been targeting the same population at each choice-point. As a result, the data before and after the intervention were not independent. A more appropriate analysis strategy would have been bootstrapped analyses to counteract the interdependence of the measured periods (Efron & Tibshirani, 1993; Good, 2005). Nonetheless, none of the effects of intervention even approached significance and bootstrapped analyses would not have changed this result.

2.7 Recommendations

It is recommended to test other types of motivational messages to promote stair use among similar target group as message based on calorific expenditure did not show any significant improvement on stair use. The height of the building should also be considered; as higher building generates higher electricity usage by the lifts. Additionally, stair use should be measured. An infrared counter should be installed to record the frequency of stair use. The placement of an observer or a video recorder adjacent to the stairwell would be beneficial in determining individual’s characteristic such as gender and directions of travel.

A semi-structured interview would be useful to gather the qualitative data on students’ experience, barriers, determinants, and suggestions of stair use if similar study to be repeated in the near future.

2.8 Conclusion

Overall, this study provided no evidence that point-of-choice prompts to encourage stair use based on weight control influenced first year’s students lift usage.

2.9 Acknowledgement

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CHAPTER 3

PROMPTED WORKPLACE STAIR CLIMBING AND EFFECTS ON GLUCOSE AND LIPOPROTEIN PROFILES: A FEASIBILITY STUDY

3.1 Abstract

Prolonged sitting is associated with increased risk of obesity, type 2 diabetes and cardiovascular disease. Occupational sitting accounts for up to 50 hours per week among employees. The objectives of this study were, 1) to assess the feasibility of the employees in incorporating stair climbing activity as an interruption to sitting throughout their working hours, 2) to determine the effects of four weeks of daily stair climbing on glucose and lipid profiles, and 3) to assess potential stair climbing habit when prompted. A total of 16 participants were recruited with an equal number of participants in control and experimental groups. A continuous four-floor stair climb was performed eight times.day^{-1}, spread evenly during the working period. A prompt to perform this climb appeared on the participant's office desktop. Participants recorded floors climbed in response to each prompt in a log sheet, and total weekly steps from a pedometer were measured. An adapted Self-Report Behavioural Automaticity Index (SRBAI) for initiation of the climb was completed at the end of every week. Blood samples were collected pre and post intervention to test effects on glucose, LDL-C, HDL-C, TC, TC/HDL-C ratio and TG. Experimental participants were interviewed at the end of the study. Results showed significant reductions in fasting blood glucose, LDL-C, TC and TC/HDL-C ratio in the experimental group. Automaticity of response to the prompt to stair climb increased but did not reach asymptotic performance. Post-experimental interviews indicated that the interruption to sitting was well tolerated. In conclusion, prompted stair climbing activity had impacts on health outcomes and was found feasible for the employees to be performed at work.

Keywords: prolonged sitting, work, point-of-choice prompts, stair climbing, feasibility, health outcomes.

3.2 Background

Sedentary behaviour differs from physical inactivity or insufficient levels of activity. The behaviour refers to sitting without performing any other activities and maintaining a sitting or reclined position with energy expenditure between 1.0 to 1.5 METs (Pate, O'Neill, & Lobelo, 2008). In this modern era, people are found to be more bound to sit while commuting, working in the office and spending leisure time on screen based media such as watching television and playing video games (Owen, Healy, Matthews, & Dunstan, 2010). People may be active for 150 minutes per week of moderate to vigorous physical activity to meet the recommendation guideline for weekly physical activity while the rest of their time is spent sitting. As pointed out by Healy et al. (2008), employees who accumulated up to 10 hours of sitting at the workplace during their non-exercise time increased the risk of obesity (Hu, 2003), type 2 diabetes, cardiovascular disease, and all-cause mortality (Grøntved & Hu, 2011). A meta-analysis of the association between objectively measured sitting and physiological outcomes after adjusted for MVPA reported convincing associations with triglycerides, insulin and its sensitivity, but less strong evidence for association with fasting glucose and glucose tolerance (Brocklebank, Falconer, Page, Perry, & Cooper, 2015).

Prolonged sitting at work has become a major public health concern. Often individuals are unaware that they are sitting, reporting that it occurs as part of a task (Martínez-Ramos et al., 2015). The cues for sitting are task related, e.g. a desk with a computer, and sitting occurs to meet the higher order goal of the task. Thus, workplace sitting may be primarily a non-conscious behaviour that facilitates the over-arching goal of the work.

Research on physical activity at work has examined changes in glucose, lipids, blood pressure and other indicators to test the physical activities (interventions) that could benefit health. For example, Osiecki et al. (2013) introduced a 15-minute exercise program involving gymnastic and relaxing activities daily during office hours for female administrative workers. After 12 weeks of intervention, significant reductions in total cholesterol (TC), low density lipoprotein cholesterol (LDL-C), triglycerides (TG) and diastolic blood pressure were reported, with some evidence of improvements in body composition (Osiecki et al., 2013). Similarly, physically inactive overweight and obese employees who were exposed to six weeks of Nordic walking activity of increasing intensities (Wiklund et al., 2014), reduced free fatty acids, fasting glucose, and insulin whereas a dietary counselling group lost weight without showing other health benefits. Nonetheless, these types of workplace intervention simply confirm the health benefit of regular physical activity; a different approach may be required to counteract the effects of prolonged sitting.

In order to combat sedentary behaviour, systematic interruptions to sitting have been trialled. Measurements of physical activity can be done by using devices such as accelerometers to estimate energy expenditure or body movements within set time periods, whereas activPAL can explicitly record postural activities such as sitting, standing and stepping. These devices can distinguish between sedentary behaviour and accumulation of physical activity during sedentary breaks for the period of any intervention. Interrupting sitting by standing every 30 minutes improved tiredness, musculoskeletal distress (Thorp, Kingwell, Owen, & Dunstan, 2014), and plasma glucose (Thorp, Kingwell, Sethi, et al., 2014). In a multi-component informational and skill-based intervention that also included provision of sit-to-stand desks to allow standing while working at a computer task, modest improvements in cardio-metabolic health have been reported (Healy et al., 2017). Nonetheless, health information about potential benefits of physical activity such as interrupting sitting will often be removed in time and place from any possible healthy choice (Eves, Webb, Griffin, & Chambers, 2012; Olander & Eves, 2011). Information targets motivation and intention to change, a necessary precursor of change. Motivational approaches can be supplemented by volitional strategies such as planning that help convert intentions into actual change (Sniehotta, 2009). Individuals imagine the time and place where the new behaviour can occur (Sniehotta, Scholz, & Schwarzer, 2005; Sniehotta, Schwarzer, Scholz, & Schüz, 2004). One volitional approach that increases physical activity provides prompts at the time a healthy choice can be made (Lewis & Eves, 2012). In these interventions, called a point-of-choice prompts, signage between stairs and escalators about health benefits increases choice of the stairs. Similar approaches have been employed to target sedentary behaviour. As noted earlier, individuals may be unaware that they are sitting for prolonged periods, and a prompt could alert them to this fact (Martínez-Ramos et al., 2015). The prompt provides a cue for action at a time when it can be taken.

A text message was sent three times daily to remind employees to stand and break up the sedentary time (Pronk, Katz, Lowry, & Payfer, 2012). Pronk and colleagues reported that sitting time was reduced by 200% which equated to one hour.day^{-1} and improved postural stress by more than 50%. Similarly, Cooley & Pedersen (2013) prompted employees by installing an e-health software program to remind them to take a break from sitting. Employees were given options to perform any physical activities that they prefer during the break including standing, stair climbing, doing photocopies, or simple exercise. The prompt message was displayed on the computer screen every 45 minutes and stair climbing was the most popular activity chosen by the employees throughout the 26 weeks of intervention. This result suggests stair climbing may be a suitable interruption to sitting. In another study, an educational talk to office workers to instil awareness of the detriment of being sedentary; i.e. an informational intervention targeting motivation, compared with prompts. Evans et al. (2012) used prompting software installed on the office workers' computer to interrupt sitting by standing every 30 minutes throughout office hours. Sedentary activity of more than 30 minutes duration was recorded using ActivPAL monitors. Only the combination of prompting and education decreased the number and duration of prolonged sitting events. This result also suggests that a multi-component approach may have more impact on combating sedentary behaviour than a single component approach. Similarly, a workplace intervention that embedded multiple methods such as involving the organisation to give support to the intervention program, introducing sit-to-stand work desks and personal face to face coaching with the employees was shown to significantly reduce the sitting time by more than two hours throughout the day (Healy et. al, 2013; 2017).

Stair climbing requires more energy per minute than jogging, being estimated as; metabolic equivalents (METs) of the resting state at 9.6 METs (Teh & Aziz, 2002) and 8.8 METs (Jetté, Sidney, & Blümchen, 1990). As a result, stair climbing is a vigorous physical activity that can be conducted at work. A seven-week intervention study by Boreham, Wallace, & Nevill (2000) used a public access staircase (199 steps, 32.8 m of height) to test effects of stair climbing on cardiovascular disease (CVD) risk factors in sedentary young women. The experimental group were asked to continuously climb the whole staircase. The number of climbs.day^{-1} increased gradually from one climb up to six climbs.day^{-1} in the final weeks. The climbing was scheduled to be spread evenly during working hours. The results showed a significant increase in HDL, a reduction in the TC/HDL-C ratio and improved indices of fitness, namely VO_2max, heart rate and lactate in the experimental group. A similar study was replicated by Boreham et al. (2005) approaching the same target group in an eight-week stair climbing intervention on the same staircases. Two continuous climbs.day^{-1}, five days.week^{-1} for the first two weeks increased to five climbs.day^{-1} in the last two weeks of the intervention. The pace of climbing was set at 90 steps.minute^{-1} and took two minutes for one complete climb. The replication revealed improved VO_2max, and reduced LDL-C level but no significant changes detected for TC, HDL-C, the TC/HDL-C ratio and TG. In agreement with the effects on aerobic fitness, Kennedy, Boreham, Murphy, Young, & Mutrie (2007) found a significant increase in VO_2max after eight weeks of a less intense intervention. Sedentary employees were asked to start with one climb.week^{-1} for the initial two weeks and add a further daily climb every two weeks until they maintained three climbs.day^{-1} in weeks five to eight of this intervention on a staircase with 145 steps (23.9 m) at

75 steps.minute^{-1}. The accumulation of six minutes climbing in three bouts daily, however, did not improve blood pressure or lipid profiles.

Little is known about the feasibility of stair climbing activities among employees when embedded throughout working hours as an interruption to prolonged sitting. The first feasibility study on stair climbing at work by Fardy & Ilmarinen (1975) among male employees found that 25 flights of stairs climbed daily improved cardiorespiratory fitness. Similar feasible results were found with female employees (Ilmarinen et al., 1979). Taking into accounts the methods and approaches reported by previously mentioned studies, the current study assessed the feasibility of the employees to climb four floors eight times.day^{-1} to interrupt occupational sitting throughout the working period during weekdays. The lesser number of floors to climb than employed by Boreham and colleagues was chosen to accommodate the environmental workload and to avoid interference with work that might not be practical for employees. Nonetheless, heart rate data from Boreham et al. (2000) suggest four floors would be associated with 85% of maximal heart rate, an appreciable physiological challenge. This study investigates how far it would impact health in terms of alterations in blood glucose and lipid profiles. Rather than individuals choosing when to stair climb, a pop up reminder was used as a prompt at which participants were requested to climb four floors of stairs continuously. This task would require approximately two minutes for the complete ascent and descent during the sedentary breaks. Interviews of the employees after the intervention aimed to provide information on the acceptability of the interruption. In addition, an adapted Self-Report

Behavioural Automaticity Index (SRBAI; Gardner, Abraham, Lally, & de Bruijn, 2012) was completed by experimental participants to test for potential habitual effects of response to the initiation of the climb. Recently, Phillips & Gardner (2016) have argued that it is the initiation of a behaviour which is the key to changing habits. We hypothesized that prompted stair climbing would be feasible for the employees and improve glucose and lipid profiles after the intervention ended.

3.3 Methods

Study design

The name of the intervention was *'Climbs at Work'*. This study was an intervention study with pre-post measures. It was not a randomised controlled trial as the participants were not randomly selected due to the limited availability of the buildings at the study site. Participants were volunteers who saw the advert or who heard about the study from their colleagues. The study started on 17th August 2015 and ended on 2nd December 2016, with the last completed participant for the experimental group.

Study site

The study was conducted at the Biosciences (four floors) and Muirhead Tower (12 floors) buildings, University of Birmingham. These sites were chosen as both were at least four-storey buildings to suit the stair climbing activity of the intervention. The staircases were located near to the participant's office and feasible to be used eight times.day^{-1}. Permission to conduct the study and install prompting software on office computers had to be obtained from each building management, in particular the IT section. In addition, we were precluded from recruiting employees working on financial tasks as the building management were concerned that the prompt might introduce errors by interrupting behaviour during an important calculation. The pre and post intervention visits were held in Human Performance Laboratory (HPL) at School of Sport, Exercise & Rehabilitation Sciences, University of Birmingham.

Study population

Advertisement posters with title “*Can you spare 16 minutes a day at work to get healthier?*” were put up on the notice board or affixed to the wall adjacent to the lift at these buildings (Figure 3.1). We hoped that the strapline including the world *‘healthier’* would recruit individuals who had intention to become healthy and hence increase their physical activity. In order to be eligible as a participant, individuals must be a) physically inactive (scoring low level of physical activity on the IPAQ), b) employed in desk-based office jobs at the University of Birmingham, c) spending most of the time sitting during office hours, d) non-smokers, e) able to climb stairs regularly, and f) healthy and not on any medication. Total number of participants for this study was 16; eight participants for the experimental and control groups. This study was a preliminary study. As Boreham et al. (2005) used a total of eight stair climbers, we used the same number of participants to provide preliminary information on potential effects on physiological outcomes. The first participant recruited in August 2015 whereas the last participant was recruited in September 2016. The recruitment for the experimental group involved employees from the two buildings at the study site, as these were the only buildings that had four and more floors. The participants in the control group were volunteers from any university buildings since they were not required to climb stairs for the study and just continue with their normal routine at work. The retention rate was 87%. as one participant recruited to the experimental group did not complete the intervention and was replaced. This dropout cited she was *‘unable to commit due to work position that involved a number of long meetings on most of the working days’* for leaving the study. The intervention was hoped to be feasible to the participants to integrate stair climbing throughout their working hours. Majority of the participants (7/8) agreed that this intervention was convenient and acceptable to them.

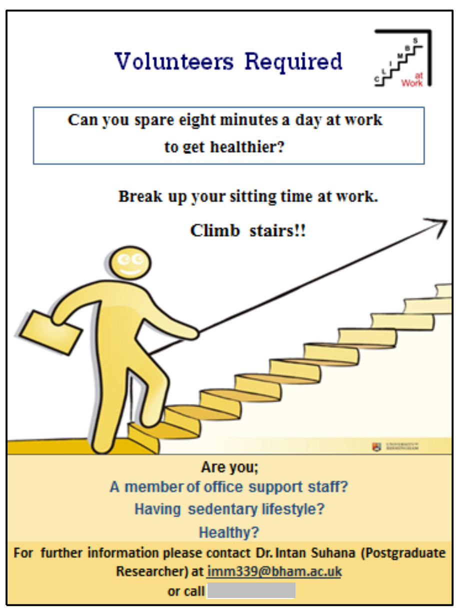

Figure 3.1 Poster used for advertisement.

Behavioural measures

Each participant in the experimental group was instructed to wear a pedometer throughout the study. Increased physical activity by performing stair climbing for eight weeks during the intervention might trigger negative spill over effect, thus causing the reduction in the number of steps during the week. At the end of each week, the number of steps was read from the pedometer by the experimenter. In addition, a weekly log sheet was given to record all the information on the stairs climbed daily from week one till week eight. Participants were instructed to log the number of floors climbed in response to each prompt received on the computer (see appendix 5). The Self-Report Behaviour Automaticity Index (SRBAI*)* questionnaire (Gardner et al., 2012) was modified to assess the potential automaticity of response to the prompt (see appendix 6; Phillips & Gardner, 2016). The four questions used the root *'Going to climb the stairs when I receive the prompt on the screen is something'* with the potential responses of *'I do automatically', 'I do without having to consciously remember', 'I do without thinking'* and *'I start doing before I realise I am doing it'.* Responses were on a seven-point scale with the anchors '*Strongly agree'* (1) and '*Strongly disagree'* (7). The SRBAI was completed at the end of each week. SRBAI was the subset of Self-Report Habit Index (SRHI) that consisted of four items and was reported to be reliable and sensitive to assess any change on behavioural pattern (Gardner et al., 2012).

Study protocol

Potential participants were given a participant information sheet to read to fully understand the study and procedures involved. One week was given to ask any questions pertaining to the study before making any decision either to become a participant or not to join the study. Those who agreed to be part of the study were given a consent form to sign. Participants consented for the complete study including the post-intervention interview for participants in the experimental group. Participants were also clear that they could withdraw from the study at any time. Taking this into account, participants in the experimental group could withdraw themselves from the study if they didn't agree with the interview. All completed participants in the experimental and control groups were given £50 and £30 shopping voucher respectively.

a) Pre-intervention visit

Participants were briefed about the study and all the procedures involved during the pre-intervention visit which took place on the first day of the study. All signed consent forms were collected. Prior to attending this visit in the morning, participants were asked to fast overnight and their last meal should be no later than 9p.m. Procedures performed during this visit were measurement of height and weight of the participant, the oral glucose tolerance test (OGTT), and phlebotomy for blood sampling. Phlebotomy was performed by the certified principal investigator. During phlebotomy, a cannula was inserted into the antecubital vein in order to withdraw blood for sampling. Participants were asked to consume a glass of concentrated sugar solution which consisted of 75mg of dextrose powder dissolved in 300ml of water.

Blood sample (10ml) was taken before the consumption of the concentrated sugar drink to determine the participant's baseline blood sugar. Then, blood sampling (5ml) was performed at 30-minute intervals until two hours after the beverage was consumed (30, 60, 90, & 120 minutes). The cannula was irrigated using 0.9% sodium chloride every 15 minutes to avoid blood coagulation. After the final blood sample was taken, the cannula was removed and participants were allowed to leave the laboratory.

The red top plastic vacutainer tubes were used to collect the blood samples. Red top blood tubes were chosen as they have clotting activators and were suitable for the collection of serum used for glucose and lipids analyses. Once blood filled into these tubes, minimum of six times inversions of the tubes were performed to activate the anticoagulant and assure good mixture with the blood. Tubes were left around 30 minutes in room temperature to allow for blood coagulation. These tubes were centrifuged at 3000rpm for 15 minutes at 4˚C to separate serum from blood. Total of 400µl serum was then pipetted into the labelled vials: 1) pre and post glucose (at 0, 30, 60, 90 and 120 minutes), 2) pre and post for triglycerides (TG), total cholesterol (TC), high density lipoprotein cholesterol (HDL-C) and low density lipoprotein cholesterol (LDL-C). The vials for post blood samples were reserved until participants came for blood collection during the post intervention session. Filled vials were kept in -20˚C freezer prior to analyses.

Throughout the study period, participants were asked to continue with their customary physical activity and diet.

b) Experimental intervention

Participants in the experimental group were asked to perform stair climbing activity daily as brief interruptions to their sedentary time at work. Participants were told to get used to the scheduled stair climbing activity during the first week, and should start with the full four-floor climb at the beginning of the second week. Participants needed to climb four floors of stairs equalling 14 metres of climb eight times.day^{-1} which summed to 32 floors.day^{-1}. Climbing four floors was estimated to take about 60 seconds with a further 60 seconds to descend.

A prompt to climb was provided by participant's desktop to climb stairs at the appointed time using the software called task scheduler. The message '*It's time for a break. Please, climb the stairs for your health*' appeared in the bottom right corner of the screen. These prompts were spread evenly throughout the day during participant's working hours, taking into account a total of eight hours of working period. For example, stair climbing could be started at 8.15am, followed by 9.15am, 10.15am and continued until the 8th climb which was at 4.15pm with an exception during the lunch break. The sitting breaks were arranged for individual participants and scheduled at five-minute intervals to avoid participants working in the same building bumping into each other during the activity. Participants were also asked to wear a pedometer that recorded total steps per day and required to complete the log sheet after each prompt every day during the week to log the number of floors of each climb. The modified SRBAI was also filled in by the participants to assess potential automaticity of response to the prompt at the end of each week. The intervention lasted eight weeks.

Participants in the control group were asked to continue with their daily routine as usual, maintain customary physical activity and not to change their diet for eight weeks.

c) Post-intervention visit

Procedures during the pre-intervention visit were repeated. In addition, experimental participants were interviewed face to face about their experiences of the stair climbing intervention. It was a short and structured interview, took approximately 10 minutes to complete. Using open ended questions, they were asked to respond in their own words to the questions '*Why did you volunteer for this study?*', '*Was the stair climbing intervention convenient/easy for you?*', '*Did the intervention help or interrupt with your work?*', '*Are you going to continue climbing stair regularly?*', '*Would you participate in this sort of intervention again?*', '*Can you think of any benefits from this intervention?*', '*Can you think of any barriers to this intervention?*', '*What would you like to improve from this activity?*', and '*What did your colleague say about it?*'. The questions provided only descriptive data and not intended for in-depth qualitative analysis. The responses were recorded verbatim.

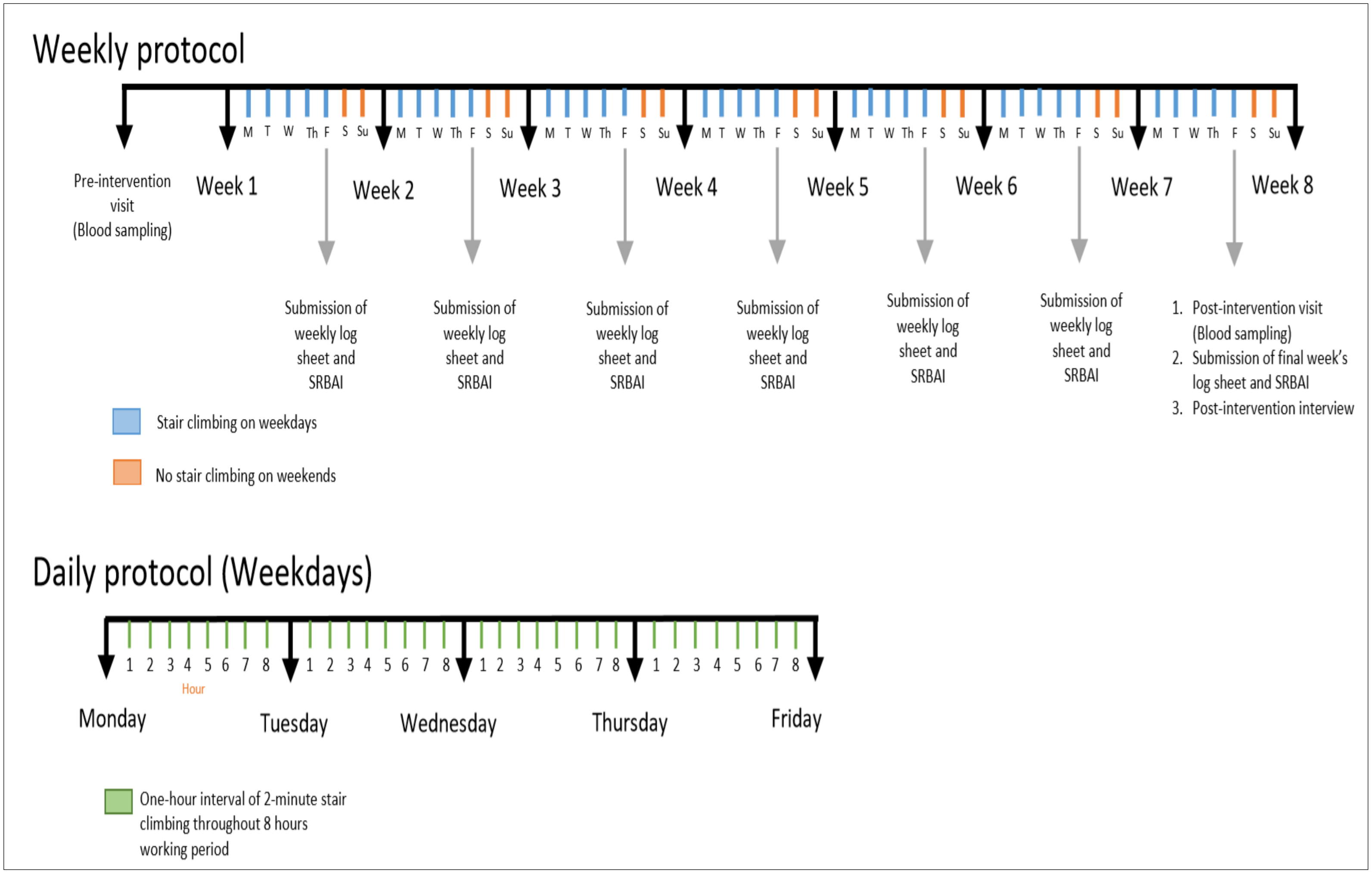

Figure 3.2 Flowchart of study protocol.

d) Laboratory analyses

Serum was analysed using a semi-automatic spectrophotometric clinical chemistry analyser, Instrumentation Laboratory (ILab 650, Cheshire, UK) to measure the concentration of glucose, TC, HDL-C, LDL-C and TG. The concentration was measured in duplicates and mean for each metabolite was determined. In addition, the TC/HDL-C ratio and TC-HDL-C were calculated from the data.

Ethical approval

Ethics for this study was approved by Science, Technology, Engineering and Mathematics Ethical Review Committee, University of Birmingham with ethics reference number ERN_15_0491.

Statistical analysis

Data were analysed using the SPSS statistical package for Windows, version 20.0. Data did not meet the assumptions for parametric statistical analysis due to the small sample size and data distributions showed skewness when tested for normality. Thus, non-parametric tests were used and median with interquartile range (IqR) was employed instead of mean and standard deviation (SD). The Wilcoxon signed rank test was used to compare the median changes (pre-post) of fasting glucose, response to the OGTT, TG, TC, LDL-C, HDL-C, and TC-HDL-C for control and experimental groups. The Mann-Whitney test was employed to examine any significant difference of pre-post changes between control and experimental groups. For the data related to changes over weeks in the experimental group, analyses employed repeated measures analyses of variance, with the single degree of freedom linear and quadratic polynomials as tests for any direction of change. For the number of floors climbed and the SRBAI, the evidence of a developing habit in the data would be a change over weeks with a reduction in response consistent with moving towards asymptotic levels. Therefore, the single degree of freedom polynomials are the key parts of the analysis. For the SRBAI, the evidence for habitual response would be a) the linear trend for increasingly automaticity over weeks, and b) quadratic trend for a curvilinear function consistent with moving towards asymptotic automatic responses.

In this study, participants were asked to climb four floors, eight times.day^{-1}, a less extensive climb than the eight floors used in the studies by Boreham and colleagues. For all these analyses, we predicted reduced levels post vs. pre for the experimental group but not for the control group with the exception of the opposite effect for HDL-C. As this is primarily a feasibility study with some physiological measures, the analyses of the physiological data did not adopt a conventional approach but rather tested the best case scenario with this relatively small sample that might be underpowered for effects of the less intense intervention than that employed by Boreham and colleagues. Nonetheless, the separate group analyses pre/post match those reported by Boreham et al. (2000).

3.4 Results

The table below displays the descriptive statistics of age and BMI for eight participants for each group, control and experimental (Table 3.1). Comparisons between the groups revealed that the age for participants in the experimental group were higher compared to those in the control group and the BMI for control group was slightly lower compared to the experimental group, but both groups were overweight.

Table 3.1 Characteristics of participants at baseline.

Variables	Control (n = 8) Mean (SD)	Experimental (n = 8) Mean (SD)
Age	36.38 (5.58)	44.75 (12.56)
BMI	29.70 (9.21)	30.78 (6.27)

3.4.1 Physiological response to the intervention

Table 3.2 summarises the median (IqR) for pre and post for both control and experimental groups. As can be seen from the table, there were no significant changes in the control group pre vs. post. In contrast, there were significant improvements in LDL-C, TC, TC/HDL-C ratio, TC-HDL-C and fasting blood glucose in the experimental group. As noted in the methods section, these analyses represent the best case scenario. Replication with a larger sample, and, hence, greater statistical power, would be required to confirm the effects relative to a control group.

Table 3.2 Median (IqR) for the study variables pre and post for the control and experimental groups, with a summary of statistical testing.

Variables (mmol.L^{-1})	**Control group (n=8)**		**Control x Pre:post**	**Experimental Group (n=8)**		**Exp[a] x Pre:post**
	Pre Median (IqR)	**Post Median (IqR)**	**Z statistic *p* value**	**Pre Median (IqR)**	**Post Median (IqR)**	**Z statistic *p* value**
TG	1.52 (1.01)	1.40 (.87)	-.70 *p* = .49	1.53 (1.00)	1.34 (1.06)	-1.12 *p* = .26
TC	5.35 (1.25)	5.30 (1.26)	-1.48 *p* = .13	5.00 (2.08)	4.70 (2.00)	-2.38 *p* = .02*
HDL-C	1.11 (.33)	1.06 (.30)	-1.36 *p* = .17	1.11 (0.58)	1.22 (0.59)	.35 *p* = .73
LDL-C	3.50 (1.08)	3.50 (1.14)	-1.41 *p* = .16	3.20 (1.53)	3.05 (1.28)	-2.20 *p* = .03*
TC/HDL-C ratio	4.94 (1.34)	4.98 (1.69)	-0.28 *p* = .78	5.30 (1.44)	4.58 (1.49)	-2.52 *p* = .01*
TC-HDL-C	4.14 (1.21)	4.11 (1.09)	-1.12 *p* = .26	3.90 (1.43)	3.64 (1.49)	-2.52 *p* = .01*
Fasting glucose	5.13 (1.09)	5.09 (1.19)	.42 *p* = .67	5.14 (.77)	4.93 (.55)	-2.24 *p* = .03*
OGTT AUC[b]	6.22 (1.97)	6.70 (1.13)	-.14 *p* = .89	7.63 (1.99)	7.26 (0.95)	-1.40 *p* = .16

[a] Exp = experimental. [b] OGTT AUC = oral glucose tolerance test, area under the curve. * p < .05

Further analysis was performed using Mann Whitney test to compare pre-post changes between both groups. There was no significant difference for pre-post changes in the control arm in comparison with the intervention arm (Table 3.3).

Table 3.3 The comparison of median (IqR) of the pre-post changes between control and experimental groups.

Variables	Median (IqR)		Z statistic	*p* value
	Control	Experimental		
Age	35.50 (9.75)	45.00 (25.75)	-1.32	0.19
BMI	29.73 (1.64)	30.46 (11.31)	-0.42	0.67
TG				
Post-Pre	-0.09 (0.52)	-0.10 (0.47)	-0.63	0.53
TC				
Post-Pre	-0.08 (0.59)	-0.20 (0.68)	-1.06	0.29
LDL				
Post-Pre	-0.15 (0.40)	-0.15 (0.58)	-0.43	0.67
HDL				
Post-Pre	-0.02 (0.09)	0.02 (0.13)	-1.06	0.29
Fasting glucose				
Post-Pre	-0.06 (0.88)	-0.32 (0.52)	-1.16	0.25

3.4.2 Behavioural response to the intervention

Table 3.4 summarises the total of steps.week^{-1} from the pedometers and the number of floors.week^{-1} recorded by participants on the weekly log sheets respectively. Week 7 showed the highest steps obtained and week 8 the lowest. We had no explanation for the abrupt reductions in total steps for week 2 and week 8. In analyses, there was a significant effect of week, $F_{(3, 21)}$ = 3.54, p = .03 after applying the Greenhouse-Geiser correction to the degrees of freedom (Epsilon = 0.428). Inspection of the single degree of freedom polynomials revealed no linear component over weeks ($F_{(1, 7)}$ = 0.46, p = .52) that would be consistent with systematic reductions in total step counts over the weeks of the study. Instead, the effects of time were described by significant quadratic ($F_{(1, 7)}$ = 6.17, p = .04; 32.4% of the variance) and cubic polynomials ($F_{(1, 7)}$ = 15.01, p = .01; 53.7% of the variance). This pattern of results does not suggest any clear reductions in step counts during the intervention that would indicate a replacement of typical stepping behavior with stair climbing (Figure 3.3).

Table 3.4 Descriptive statistics on pedometer measured steps and floors climbed by participants during the eight week intervention (n = 8).

Time	**Total Steps**	**Total Floors Climbed**
	Mean ± SD	**Mean ± SD**
Week 1	51883 ± 14675	134 ± 16
Week 2	45840 ± 8205	122 ± 23
Week 3	49552 ± 18663	109 ± 29
Week 4	56742 ± 17762	134 ± 25
Week 5	57253 ± 17865	129 ± 28
Week 6	58711 ± 23416	112 ± 48
Week 7	60129 ± 22769	124 ± 33
Week 8	43442 ± 12150	103 ± 32

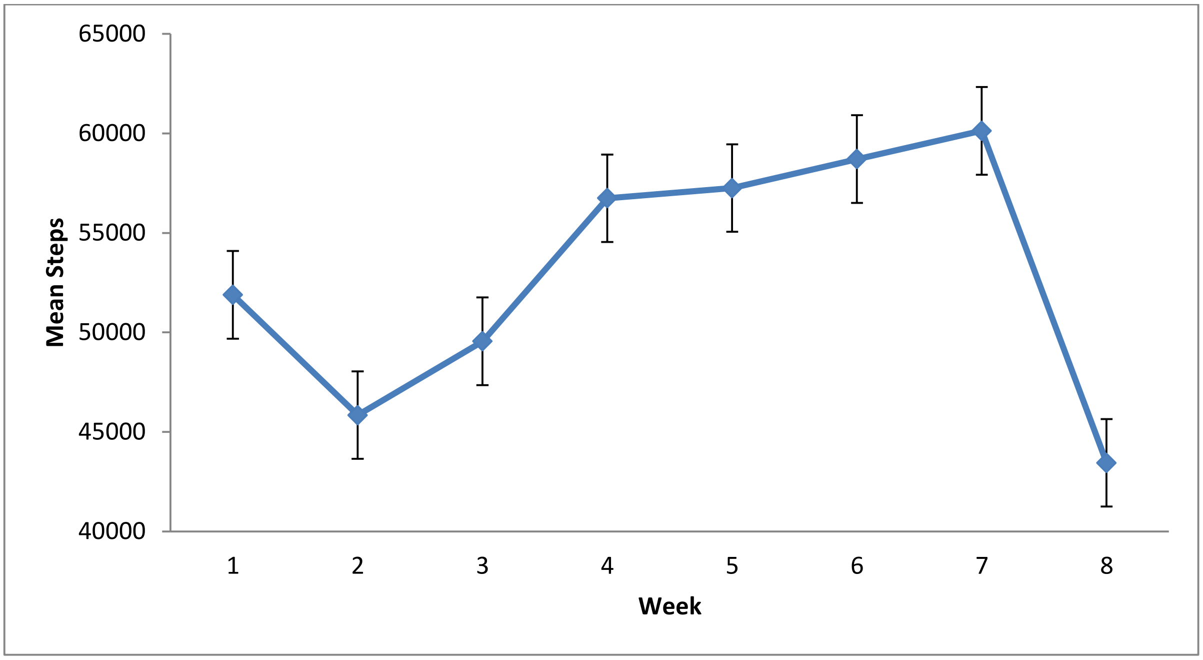

Figure 3.3 Pattern of weekly steps by experimental group (n = 8).

In analyses of the number of floors climbed, there was no main effect of week, $F_{(4,\ 25.1)} = 1.82$, $p = .16$ after applying the Greenhouse-Geiser correction to the degrees of freedom (Epsilon = 0.512). The linear, quadratic and cubic polynomial trends were all non-significant (all prob > .18). These data do not suggest any incremental effects on the number of floors climbed over the period of the intervention. Instead, there is some variation over weeks that reflect individual variability in response to the prompt (Figure 3.4).

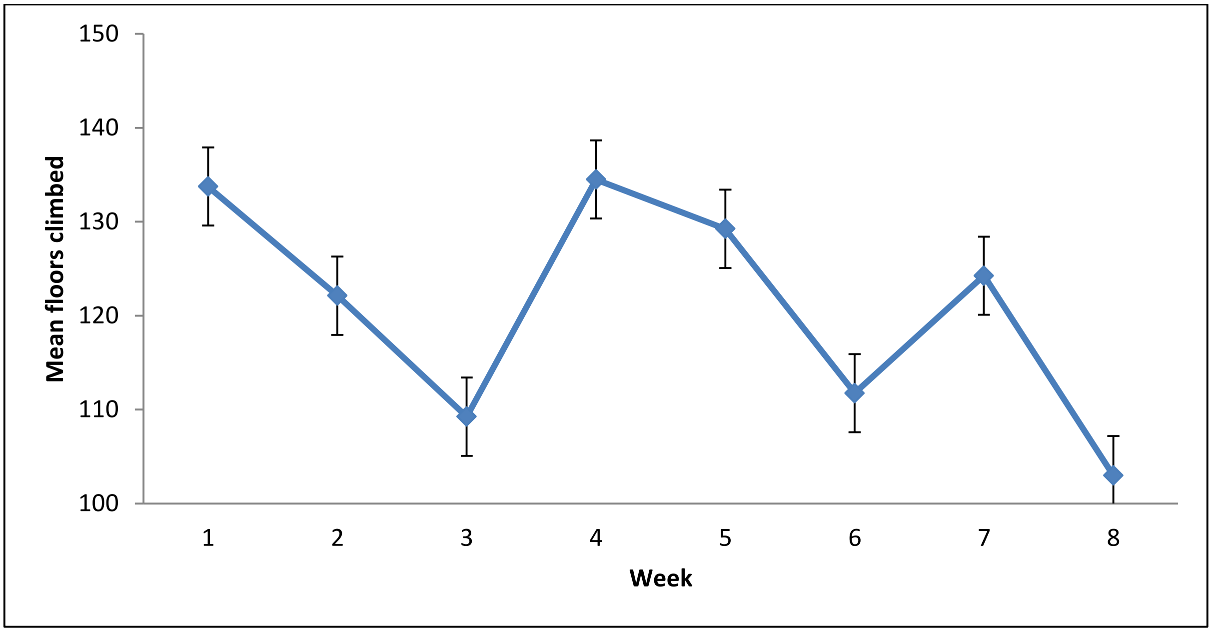

Figure 3.4 Pattern of weekly climbs by experimental group (n = 8).

Self-reported measure was used to determine intervention fidelity. As stated earlier, participants were asked to report on the number of stairs climbed daily on the log sheet and submitted the report every week. On average, the experimental group climbed 121 (20) floor.week^{-1}, equivalent to 3388 meters of climbing over the duration of the experimental period. The sharp reduction of total floors climbed in week 3, 6, and 8 could be due to the interruptions to the hourly stair climbing activity as some of the participants could be involved with long meetings, attending seminars or workshops, working remotely from their workstation, or taking a leave. Only 12.5% of the participants climbed 160 floors for the whole week for most of the weeks, except in week 4 whereby 37.5% of the participants managed to adhere to the requirement of climbing four floors of stairs, eight times per day during the weekdays.

Individual report for the number of floors climbed weekly as shown in Table 3.5. The highest average of floors climbed was 144.3 and the lowest was 91.

Table 3.5 Individual report on number of floors climbed (n = 8).

Participants ID	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7**	**Week 8**	**Average floors climbed per week**
E01	132	96	100	124	124	128	148	84	117
E02	160	96	128	160	160	128	128	68	128.5
E03	116	160	64	160	148	156	128	124	132
E04	116	112	88	118	94	38	98	64	91
E05	132	112	88	104	84	68	56	114	94.8
E06	134	120	116	160	144	160	160	160	144.25
E07	128	133	138	102	128	64	128	118	117.4
E08	152	148	152	148	152	152	148	92	143

3.4.3 Reported automaticity of response to the prompts

To reiterate, participants in the experimental group (n = 8) were given the SRBAI form to be completed at the end of the week to assess their reported behaviour upon receiving the prompt on the screen to go and climb the stairs. We hypothesized that the participants might develop automaticity in their instigation of the behavior towards the end of the intervention. On the seven-point scale, one represented strongly agree that the behavior was automatic, with 3.5 the mid-point of the scale.

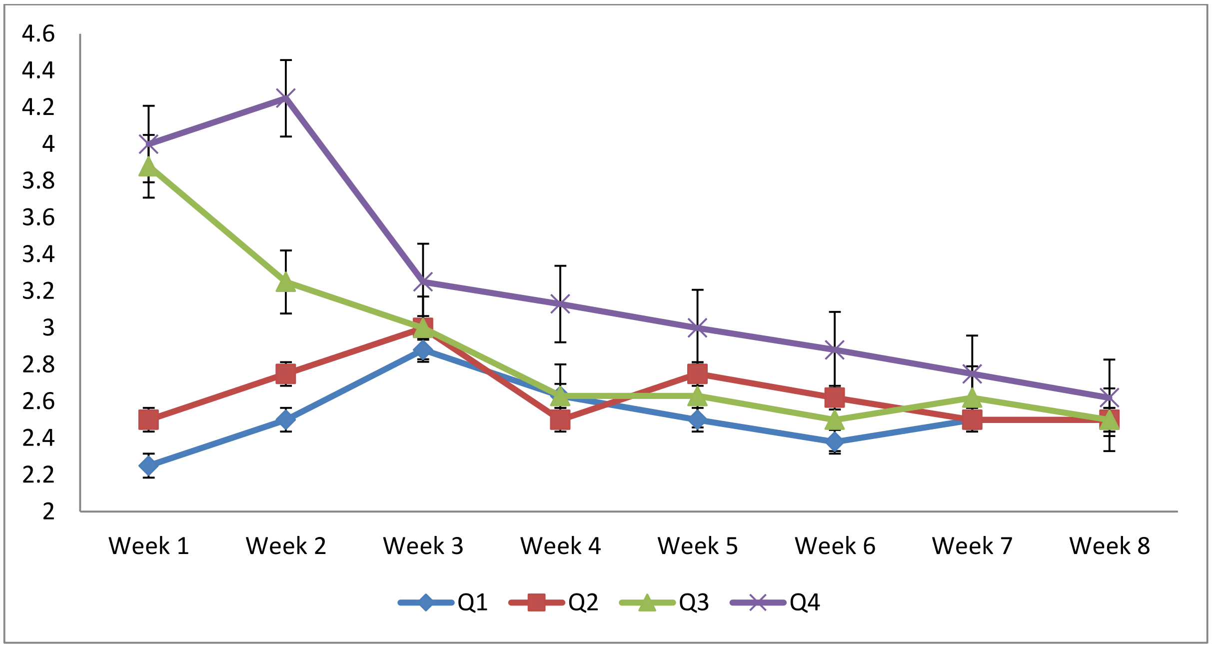

Figure 3.5 Graph showing the responses to each question of the SRBAI.

Q1: I do automatically, Q2: I do without having to consciously remember, Q3: I do without thinking, and Q4: I start doing before I realise I'm doing it.

As this was an exploratory study, the preliminary omnibus analysis included each question separately. The analyses contained a main effect of question, $F_{(2,\ 13.1)}$ = 11.49, p = .01 after applying the Greenhouse-Geiser correction to the degree of freedom (Epsilon = 0.628), and an interaction between question and the non-significant main effect of the week ($F_{(3,\ 22.4)}$ = 11.49, p = .04; epsilon = 0.153). Inspection of the response to separate questions in the figures suggests that the first two questions, '*I do automatically*' and *'I do without having consciously remember'*, were in the agreed part of the seven-point scale by the time the questionnaire was administered at the end of the first week. There was no evidence of any consistent change over the subsequent weeks of the study. In contrast, question three ('*I do without thinking*') and question 4 ('*I start doing before I realise I'm doing it*') were in the less agreed part of the seven-point scale at the end of the first week, with rated agreement changing over the period of the study to more agreement (Figure 3.5). Analyses of these two questions together revealed a main effect of week, $F_{(2, 13.8)} = 4.46$, $p = .03$; epsilon = 0.282, with the linear polynomial trend ($F_{(1, 7)} = 8.85$, $p = .02$) explaining 84.7% of the variance of the effect over week. The quadratic trend that would suggest progress towards asymptotic response was not significant ($F_{(1, 7)} = 2.50$, $p = .16$).

3.4.4 Individual reports about the feasibility of the intervention

Table 3.6 summarises the experimental participant's responses during the post-intervention interview. Concerning acceptability of the intervention, experimental participants enrolled in the study for physical activity and as a motivation to get healthier (7/8) and the majority reported resultant beneficial effects on health (6/8). Most found it easy or convenient to complete the stair climbing (7/8) and reported the breaks helpful to their work (6/8). Nonetheless, two questioned the sustainability of eight daily climbs. Unsurprisingly, the reported barriers were that it sometimes also interrupted their work (5/8) and did not always fit within a busy schedule (4/8). Nonetheless, seven said they would continue to climb stairs regularly, with the only dissenter, a retiring employee who would not have easy access to a sufficiently tall building, planning to walk more instead.

Table 3.6 Participant responses to the post intervention interview questions.

Items	Questions	Participants responses
1.	Why did you volunteer for this study?	E01 – Enjoy participating and potential health benefit E02 – To undertake regular exercise to get fitter E03 – Try to get healthier E04 – Want to exercise E05 – To help and to get fitter and to see what difference does it make E06 – To increase exercise and reduce weight E07 – To test my ability & stamina E08 – Helping a friend in research
2.	Was the stair climbing intervention convenient/easy for you?	E01 – Yes easy, although going and climb the stairs every hour eight times a day is not sustainable E02 – It was convenient as the stairs were easily accessible E03 – It was moderate, not that easy E04 – Yes easy E05 – Easy, just the hour between climbing was too quick E06 – Yes convenient, very accessible E07 – In the beginning it was easy, but towards the end it became quite demanding E08 – Yes
3.	Did the intervention help or interrupt with your work?	E01 – Both, provide useful breaks but sometimes breaks were inconvenient E02 – Did interrupt with my work some days, and on really busy days with lots of meetings and difficult to fit in E03 – Helped E04 – Yes it helped E05 – Sometimes it did interrupt E06 – Helped, as not continuously sitting all day E07 – It helped with my concentration and focus because it kept me awake, only when I was in hurry or needed to attend other matters it became demanding E08 – Little bit of both, depending on my schedule
4.	Are you going to continue climbing stairs regularly? Why?	E01 – Yes, the study made me realised how sedentary my office day is E02 – No, will be retiring and don’t have access to many

		stairs but will walk more E03 – Yes, will continue with 2 floors (to keep fit and get away from sitting in front of computer) E04 – Yes, I have definitely felt fitter because of that E05 – Yes, try to do it regularly E06 – Yes, feel better E07 – Yes, it becomes a preference now E08 – Yes
5.	Would you do this activity again?	E01 – Yes E02 – Possibly, given the opportunity E03 – Yes, if only 2 floors E04 – Yes E05 – Yes E06 – Yes E07 – Yes E08 - Yes
6.	Can you think of any benefits from this intervention?	E01 – Feel fitter, more alert & help with my concentration E02 – I felt slightly fitter and it certainly made me think about being more active E03 – To get away from the screen, and take a break from work E04 – I realise that I do not exercise enough E05 – Loss of weight, feel fitter E06 – Yes, it makes me realise lack of exercise/walking I undertake E07 – Yes, it increased my focus E08 – Increased stamina
7.	Can you think of any barriers to this intervention?	E01 – Not sustainable for long term, in some days it surely doesn't happen E02 – None E03 – No E04 – No E05 – The clash when students are crowd E06 – Volume of work, meetings, not always allow for it E07 – Clashed with personal schedule (holiday & vacation or unexpected occasions)

		E08 – During tight schedule (meeting, lab etc.)
8.	What would you like to improve from this activity?	E01 – Nothing E02 – Fitness level E03 – I wish if you can replace that horrible glucose drink with something else E04 – Nothing E05 – Fitness level E06 – None E07 – Consistency E08 – Motivation
9.	What did your colleague say about it?	E01 – They were interested, some thought a bit odd when they saw me climbing stairs. E02 – They were interested E03 – Influenced other colleagues to climb stairs E04 – They seem interested to climb 2 flights of stairs hourly E05 – Nothing E06 – Found it useful and good to help with exercising E07 – Requires great commitment and challenging E08 – Interesting research

3.5 Discussion

This study focussed on the feasibility of sedentary university support staff to incorporate stair climbing activity as an interruption to sitting into their working hours. A total of four floors of continuous climbing which equated to 14 meters of height for one complete climb was chosen to assure achievability of completing eight ascents.day^{-1} when spread evenly during eight hours of the working period. The stair climb was scheduled hourly to increase the number of breaks from prolonged occupational sitting. Each completed ascent and descent took approximately two minutes with a target of 160 floors accumulated per week. On average, the experimental group climbed 121 (20) floors.week^{-1}. In the original feasibility studies, Fardy and Ilmarinen (1975) reported improvement in cardiorespiratory fitness in male participants who climbed 125 floors or more per week over 12 weeks whereas Ilmarinen et al. (1979) reported significant decrease of Ratings of Perceived Exertion (RPE) for female employees who performed 65 floors of stair climbing weekly with each climb lasting one minute over a 24-week period. Ilmarinen et al. (1979) reported that this modest amount of extra floors was feasible to be completed during working days. This resulted in recommendation to climb more than 13 floors.day^{-1} to produce effects on fitness (Ilmarinen et al., 1979).

From the data in this study, 24.2 floors.day^{-1} proved feasible for office workers. Further, interviews after the intervention indicated that most employees found it was easy or convenient to complete the stair climbing and, for some, that the breaks during the day were helpful to their work. Nonetheless, sometimes the prompt interrupted their work and completing the climb did not always fit within their busy schedules. Indeed, the latter was the main reason why one recruited experimental participant did not complete the study; frequent meetings that she could not leave meant that she felt obliged to withdraw. Stair climbing as an interruption to sitting would only be feasible for office workers where most of their time was spent working at the same desk and are not constrained by long meetings. Two questioned the sustainability of eight daily climbs. The caveat by employees that they could not always interrupt their work will be relevant to the assessment of potential habitual responses to the prompt. Importantly, most participants joined the study for health reasons, a factor underscored by the overweight status of the experimental group, and reported feeling benefits to their health. This point is encouraging that roll out of such an intervention might attract employees for whom increased stair climbing would be beneficial and that these benefits might be felt by participants. Prompts worked for those with prior intentions to be more active (Lewis & Eves, 2012; Olander & Eves, 2011). In this respect, the advert appears to have recruited primarily the target group for such an intervention. From an organisational perspective, any programme of interrupted sitting would need support from the buildings management, in particular the IT department. In addition, we were precluded from recruiting employees in finance as the management were concerned that the prompt might introduce errors by interrupting concentration during an important calculation. On the plus side, it seems likely that interruptions to the working day that total only 16 minutes would be acceptable to employers.

Habits have been conceptualised as consistent impulses to respond to environmental cues (Gardner, 2015). If an employee is constrained by their on-going work so that they cannot interrupt it, then weaker links between the prompting cue and the response are likely. As Gardner (2015) has pointed out, habitual response to a cue are likely to occur at the demarcation between different behavioural sequences. Response to the prompts has to be postponed until the on-going behaviour is completed. As a result, it is possible that habitually automatic initiation of the response to the prompt could not develop. In the exploratory analyses of the adapted SRBAI, two out of the four questions, *'I do automatically'* and *'I do without having to consciously remember'* were agreed to at the end of the first week, with average values of 2.25/7 and 2.50/7 respectively. Reports of agreement with these questions did not change over the study. In contrast, *'I do without thinking'* and *'I start doing before I realise I'm doing it'* were near the midpoint of scale, 3.88/7 and 4.00/7 respectively, with increasing agreement during the study to end values of 2.50/7 and 2.63/7 respectively. Nonetheless, the change was primarily linear with no evidence of a negatively accelerated function that would suggest approach to asymptote that may be characteristic of habitual behaviours (Lally, Van Jaarsveld, Potts, & Wardle, 2010). We have no explanation for the differences between questions here. Each week, participants would have been exposed to 40 potential instances of cue-response linkage. Why there were differences between the questions at the end of the first week is unknown.

The current study involved climbing eight ascents.day^{-1} with total of 32 floors daily. There were no changes in the control group, consistent with Boreham et al. (2000; 2005). For the experimental group, there were significant improvements of LDL-C, TC, TC/HDL-C ratio, TC-HDL-C, termed 'bad cholesterol', and fasting blood glucose. In contrast, Boreham et al. (2000) with six ascents.day^{-1} reported improvements in TC, HDL-C and TC/HDL-C ratio whereas Boreham et al. (2005) with five ascents.day^{-1} improved LDL-C. The improvements with a four-floor climb, eight times.day^{-1} appear to have similar effects to the eight-floor climbs in Boreham and colleagues research. Further, Kennedy et al. (2007) with only three ascents.day^{-1} did not record any changes in lipoprotein profiles. These preliminary data suggest that more frequent climbs of a lower height of climb could have comparable effects to the eight-floor climbs. This is potentially important in terms of feasibility for employees as the lower climb entails a shorter interruption during the working day. It also seems likely that interruptions to the working day that total only 16 minutes would be acceptable to employers. Similar to the data here, a reduction of LDL-C was found in a 12-week stair climbing campaign by Meyer et al. (2010) with daily climbing of 21 staircases among employees in the Geneva Hospital building. LDL-C is known to be strongly associated with increased risk of coronary heart disease and the reduction of LDL-C would benefit in combating hyperlipidaemia and reducing the risk of ischaemic events (Wadhera, Steen, Khan, Giugliano, & Foody, 2016). There was no difference between pre and post intervention for HDL-C, and TG for the current study. This result may be due to the relatively low levels of these biomarkers at baseline. Lack of difference between pre and post for HDL-C might due to the changes of lipid concentration following the effect of the last stair climbing day since blood sampling was performed within 24 to 48 hours after the intervention ended (Crouse et al., 1997). Alternatively, biomarker profiles will be affected by the meal consumed on the evening prior to the test. Any variation between the pre and post intervention tests would add noise to the data. Nonetheless, a small asymptotic increase of 0.11 $mmol.L^{-1}$ of HDL-C was noted in the experimental group after intervention which was estimated by Gordon et al. (1989) to decrease the risk of CHD between 6 to 9% in the upcoming years.

Fasting blood glucose and 2-h OGTT for both groups, control and experimental were within the normal values at baseline, <5.6 mmol and <7.8 mmol respectively (The Expert Committee on the Diagnosis and Classification of Diabetes, 2003). Despite this, a reduction of fasting blood glucose was found in the experimental group upon completion of the intervention. The most similar evidence found for improved glucose concentration after stair climbing activity was among middle aged males who performed repeated three minutes bouts at 60 and 120 minutes after meal for two weeks (Honda et al., 2016) and six minutes bouts, 90 minutes after a mealtime (Takaishi, Imaeda, Tanaka, Moritani, & Hayashi, 2012). However, these two studies tested individuals with type 2 diabetes and impaired glucose tolerance respectively. This suggests that stair climbing with appropriate designated volume could improve glucose concentration in participants with normal plasma glucose. It seems likely that greater effects might be obtained in those with elevated plasma glucose and also diabetic individuals who would have higher baseline values.

3.6 Strengths and limitations

To date, this is the first study tested on the feasibility of the employers to climb four floors of stairs throughout working period. This study highlighted an alternative (i.e. stair climbing) to the common physical activities at work such as standing and walking, but with greater energy expenditure. Apart from that, this study was conducted in the employers' context and work location, thus, the findings represent the real world applicability and feasibility. This was also a cost effective intervention as the use of task scheduler and stairs required zero cost but able to improve health of the employees. However, this study has several limitations. The study design was not a randomised control trial as we used the self-selection sampling. Furthermore, the small sample size of the study had reduced the potential for significant improvement on certain biomarkers and the findings could not be generalised to the population. Thirdly, there was no follow up after the intervention ended to observe the sustainability of the stair climbing acitivity.

3.7 Conclusion

There were significant improvements found after eight weeks of stair climbing in LDL-C, TC, TC/HDL-C ratio, TC-HDL-C and fasting blood glucose. However, HDL-C, TG and post prandial blood glucose in the OGTT did not show any significant changes. There was some evidence that stair climbing in response to the prompt became more habitual but no evidence of approaching asymptotic performance. Post intervention data indicated that the interruptions to sitting were feasible for most and seen as beneficial by the participants. All participants able to do so reported that they would continue to climb more stairs in the near future.

3.8 Future directions and recommendations

This study only displayed similar message content to all the participants. Ideally, we should have also asked the participants during the post-intervention interview on how the content of the prompt acted as a cue for them to climb the stairs. Further, the content of the prompt could be tailored to suit the intention of the participant when they first decided to join the study. In addition, together with the prompt, a simple health education message could be added to see how it may help in keeping the participants motivated throughout the intervention period. Regarding the sample size, it is recommended to conduct a randomised control trial with larger sample size as this will improve the generalizability and potential effects of the biomarkers. Thirdly, this study used self-reported data to monitor the intervention fidelity. Participants submitted weekly log sheet that recorded the number of stairs climbed daily for the whole week, hence, assessing participants' adherence to the intervention. However, this method might compromise the validity and accuracy of the data as it influences the participants to answer according to their desire to be perceived as following the intervention protocol. This could lead to inaccurate and overstated reports of fidelity. Hence, it is suggested to use other methods for fidelity assessment such as direct observation or video recording in obtaining reliable fidelity data.

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CHAPTER 4

INTERRUPTED SITTING AT WORK CAN ALTER POSTPRANDIAL GLUCOSE, TRIGLYCERIDES AND NON-ESTERIFIED FATTY ACIDS (NEFA)

4.1 Abstract

Prolonged sitting at work is a major health issue as sedentary behaviour has been linked to cardio-metabolic risks. Workplace interventions have trialled intermittent interruption to sitting throughout the working day to mitigate effects on employees' health. This study tested effects of the intensity of the interruptions to sitting on postprandial glucose, triglycerides and non-esterified fatty acids in a laboratory setting. Overweight and obese adults (n = 24) were recruited for a randomised cross over trial comparing, 1) uninterrupted sitting, 2) sitting interrupted by light intensity walking at 3 $km.hr^{-1}$, and 3) vigorous intensity stair climbing at 60 $steps.min^{-1}$. The interruptions to sitting were performed for two-minute bouts every 20 minutes following a meal. The moderate fat meal was provided two hours after the trial started and blood samples were collected each hour throughout the seven-hour sessions. There was a lower postprandial peak in plasma glucose and attenuation of the non-esterified fatty acids reductions for stair climbing compared to uninterrupted sitting. In contrast, triglycerides were reduced postprandially following light intensity walking compared to uninterrupted sitting. These data do not demonstrate greater improvements postprandially with the greater the intensity of the interruption to sitting.

Keywords: interrupted sitting, light intensity walking, stair climbing, postprandial glucose, lipids

4.2 Background

Adults can spend up to half of their waking hour sitting (Smith et al., 2018) with sitting in the workplace making a major contribution to this total (Parsons, Thomas, & Power, 2009). Prolonged sitting is associated with increased cardio-metabolic risk; increased in BMI and waist circumference, impaired levels of high density lipoprotein cholesterol (HDL-C), elevated triglycerides and postprandial glucose in the circulation are associated with sedentary behaviour (Bellettiere et al., 2017; Brocklebank, Falconer, Page, Perry, & Cooper, 2015; Dunstan et al., 2012). Many public health agencies have developed sedentary behaviour guidelines to combat prolonged sitting (Australian Government Department of Health, 2014; Department of Health, 2011; McGuire, 2014). The recommendations are to not only reduce the amount of sitting but also to interrupt sitting regularly (Fritschi & Quinn, 2010). In epidemiological data, the duration of objectively measured sitting and the number of interruptions have been independently associated with cardio-metabolic risk (Healy et al., 2008; 2011).

Physical activity performed in short bouts to interrupt sitting, regularly incorporated into the daily routine, has been shown to be more effective than a single equivalent session of continuous physical activity (Duvivier et al., 2017; Miyashita et al., 2015; Peddie et al., 2013). Since the main barrier to promoting sedentary breaks among employees may be a lack of work flexibility (Taylor et al., 2013), frequent short sedentary breaks might avoid disruption of office tasks and increase the feasibility of interventions while at work. Interrupted sitting interventions have been conducted in adults who were healthy and of healthy weight (Altenburg, Rotteveel, Dunstan, Salmon, & Chinapaw, 2013; Bailey & Locke, 2015; Danquah et al., 2016; Healy et al., 2017; Peddie et al., 2013), those who were sedentary and inactive (McCarthy et al., 2017; Pulsford, Blackwell, Hillsdon, & Kos, 2017) and those who were overweight and obese (Dempsey et al., 2016; Dunstan et al., 2012; Henson et al., 2015). Laboratory studies of interruptions to sitting usually involve cross-over designs in which effects during a day of uninterrupted sitting, are compared with days on which interruptions to sitting with short periods of physical activity are spread evenly during the day. Typically, individuals receive a standard 'meal' in liquid form after two hours of uninterrupted sitting, with any physical activity interruptions beginning in sometime after the meal (ranging from 15 minutes to two hours). As a result, these studies test effects of physical activity interruptions on postprandial metabolism, the time at which increase concentrations in the bloodstream confer most risk (Solomon, Eves, & Laye, 2018). The area under the curve (AUC) over time measures the changes postprandially. For example, Peddie et al. (2013) reported reductions in postprandial insulin and glucose, sitting was interrupted with walking (46% VO_2max) for 100 seconds every 30 minutes, in comparison to sitting uninterrupted in a nine-hour laboratory protocol. In a similar seven-hour protocol, Dunstan et al. (2012) reported reductions in postprandial insulin and glucose when testing 120 seconds of light (3.2 $km.hr^{-1}$) and moderate (5.8-6.4 $km.hr^{-1}$) intensity walking every 20 minutes against uninterrupted sitting. Concerning the intensity of physical activity interruptions, periods of standing, light intensity walking and more intense activity that represent at least moderate intensity, i.e. Peddie et al. (2013), have been employed. Sufficient studies with glucose and insulin allow assessment of the effects of intensity. The findings have been mixed. A meta-analysis on observational and experimental studies on effects of sedentary breaks towards adiposity and cardio metabolic markers was reviewed by Chastin and co-workers. Findings from the observational studies suggested no associations of breaks with other cardiometabolic health markers except for BMI. As for experimental studies, light intensity physical activity (LIPA) and moderate to vigorous intensity physical activity (MVPA) were reported to improve postprandial blood glucose and insulin in adults but had no effects on lipid profile. The findings also revealed that LIPA and MVPA also reduced inflammatory response in adults. Additionally, shorter intermittent breaks showed greater reduction in blood glucose but failed to improve insulin and lipids levels in comparison with prolonged single bout (Chastin, Egerton, Leask, & Stamatakis, 2015).

For standing, the activity trialled with public health interventions that use ‘sit-to-stand desks’, Henson et al. (2015) reported reduced AUC following the meal for glucose and insulin whereas neither Pulsford et al. (2017) nor Bailey & Locke (2015) reported any differences from sitting for glucose and insulin or glucose respectively. In a 27-hour protocol, effects of intermittent standing after the first meal on glucose but not insulin were reported whereas an interruption of 30 minutes of moderate intensity walking reduced both glucose and insulin in the same period (Benatti et al., 2017). It is noteworthy that the Henson and co-workers sample were overweight and obese women with impaired glucose metabolism at baseline whereas the null findings for standing employed healthy individuals. Consistent with this potential effects of the sample, Thorp et al. (2014) reported reductions in glucose AUC after five days of intermittent standing in a simulated office environment for overweight and obese participants on the fifth day, though there were no effects on insulin. For light intensity walking, Bailey and Locke (2015; 3.2 $km.hr^{-1}$) reported reductions in glucose whereas Pulsford et al. (2017; 3.6 $km.hr^{-1}$), McCarthy et al. (2017; 3.0 $km.hr^{-1}$) and

Henson et al. (2015; individually selected light intensity) reported reductions in both glucose and insulin consistent with the results in Dunstan and co-workers' original study. As noted earlier, both Bailey and Locke (2015) and Pulsford et al. (2017) used healthy participants, as did McCarthy et al. (2017). With moderate intensity walking, both Peddie et al. (2013; individually determined from VO_2max) with a large healthy sample and Dunstan et al. (2012; 5.8-6.4 $km.hr^{-1}$) with overweight and obese participants reported reductions in glucose and insulin. In the only formal comparison, Dunstan et al (2012) reported greater effects of moderate intensity walking than light intensity walking on metabolic responses. Nonetheless, a null finding for glucose with moderate intensity interruptions of cycling at 52% of heart rate max has been reported in a young, healthy sample (Altenburg, Rotteveel, Dunstan, Salmon, & Chinapaw, 2013), with a similar null result in physically fit children performing a mixture of light intensity walking with moderate physical activity every 20 minutes (Saunders et al., 2013).

Overall, the summary above suggests two conclusions. First, samples of overweight and obese populations, i.e. those at greater cardio-metabolic risk, may be more affected by interruptions to sitting than healthy adults. Second, while minor differences in protocols between studies may contribute to inconsistencies, the intensity of the physical activity interruption appears important. A minimum of light intensity walking may be required (Chastin et al., 2015). Exploratory analyses of the Australian group's overweight samples with consistent methodology revealed greater effects with the greater intensity of physical activity performed during the interruption (Larsen et al., 2017). Such a result would be consistent with greater effects of more vigorous physical activity on cardio-metabolic risk than less intense activity in epidemiological data (Janssen & Ross, 2012; Laursen, Kristiansen, Marott, Schnohr, & Prescott, 2012; Yates et al., 2015).

Stair climbing requires more energy per minute than jogging, having been estimated as 9.6 metabolic equivalents (METs) of the sedentary state in the field (Teh & Aziz, 2002) and 8.6 METs under laboratory conditions (Bassett et al., 1997). As such stair climbing is a vigorous physical activity. Experimental studies reveal that increased stair climbing can have effects on some cardio-metabolic risk factors (Boreham et al., 2005; Boreham, Wallace, & Nevill, 2000; Honda et al., 2016, 2017; Takaishi & Hayashi, 2015). To date, however, the effects of stair climbing have not been investigated as an interruption to sitting. The current study aimed to compare the acute effects of prolonged uninterrupted sitting, with light intensity walking and the vigorous intensity physical activity of stair climbing on postprandial glucose, triglycerides (TG) and non-esterified fatty acid (NEFA). NEFA is free fatty acid (FFA) derived from the hydrolysis of fat or triglyceride in adipose tissue (Frayn, 2005). NEFA is a risk factor for non-insulin-dependent diabetes mellitus (Paolisso et al., 1995) and coronary heart disease (Frayn, Williams, & Arner, 1996). In the only study to have assessed it, interruptions to sitting attenuated the postprandial reductions in NEFA relative to uninterrupted sitting (Henson et al., 2015).

Consistent with Dunstan et al. (2012), we recruited an overweight and obese sample given the suggestive evidence that greater effects might be expected in a less healthy sample. Based on the intensity of the interruptions, we hypothesized that regular 120 seconds bouts of stair climbing every 20 minutes would have greater effects compared to 120 seconds of light intensity walking, which in turn would reduce elevations in glucose and triglycerides, as well as attenuate NEFA reductions, postprandially relative to uninterrupted sitting.

4.3 Methods

Study site

The intervention was conducted in the Stair Laboratory of the School of Sports, Exercise & Rehabilitation Sciences at the University of Birmingham. The laboratory contained a motorised stairmill (StairMaster 7000), a Woodway treadmill and a designated area for sitting. A television and CD player were available to be used by participants throughout the trials.

Study population

Volunteers were recruited from a population within one-mile radius of the university. Posters were placed on the notice boards in the university buildings as well as distributed outside the campus adjacent to the university entrance to the pedestrians. Some participants heard about the study by word of mouth. Inclusion criteria involved: 1) overweight/obese, 2) healthy and not on any medication, 3) no knee or joint problem, 4) no restrictions on movement, and 5) physically inactive (less than 60 $min.wk^{-1}$ of MVPA). The exclusion criteria were; 1) pregnant, and 2) physically active. Two dropouts due to problems in accessing the vein for cannulation were replaced.

Figure 4.1 Advertisement poster.

Study design

This intervention was a randomised, counterbalanced cross-over design. The total number of participants was 24, seven females and 17 males. This study began on 13th September 2016 and ended on 6th December 2016.

Study protocol

The information sheet was emailed to the volunteers to allow them to fully understand the details of the study. They were also asked to complete physical activity readiness (PAR-Q) and International Physical Activity Questionnaires (IPAQ). Those who were found eligible and agreed to join this study were given a consent form. Prior to the starting of the trials, participants were randomly assigned into one of eight groups. Each group was arranged to complete three sessions in a counterbalanced order involving the three different physical activities; uninterrupted sitting, walking and stair climbing. A minimum of six days of wash out period was kept between the sessions. A food diary completed on the day before first session was employed so that participants would eat the same food prior to each subsequent testing session. Participants were restricted from: 1) performing moderate to vigorous exercise within 48 hours prior to the start of each session, and 2) consuming alcohol the night before the session. Participants fasted overnight and refrained from drinks containing caffeine on the day of testing. Prior to the testing protocol, a baseline session was conducted to measure weight, height and BMI of participants and familiarised them with the equipment; namely the stairmill and treadmill before the day of testing. Participants who completed all three sessions were paid £200.

a) Testing session

Participants arrived at the laboratory at 8.30am. An indwelling cannula was inserted into participant's antecubital vein for the purpose of blood collection. The testing session started at 9am. with hourly withdrawal of 5ml of fasting blood sample (-2h, -1h and 0h). After sitting for two hours, participants were provided with a moderate fat meal containing 35% fat, 47% carbohydrate and 18% protein providing 68.6 kJ energy per kg body mass (Hurren, Eves, & Blannin, 2011) as the British diet is moderate in fat. This was a recommended dietary intake of energy and macronutrients for adults following the UK government guidelines (Scientific Advisory Committee on Nutrition, 2011) and the calculation of total energy was based on participant's weight. The moderate fat meal comprised of a drink containing skimmed milk, single cream, sugar and flavoured yogurt, along with an energy bar, veggie snacks and fruit. The meal was consumed within 20 minutes before starting the first interruption with physical activity. Blood was collected every hour after the meal and the catheter was flushed every 15 minutes to avoid coagulation. Blood was transferred into red top vacutainer containing clot activator and left 30 minutes in room temperature to allow clotting. Samples were then centrifuged at 3000 rpm for 15 minutes at 4˚C and kept in a -20˚C freezer prior to analysis.

Each day's session involved three participants. One participant of the group completed sitting uninterrupted, while the others either walked on the treadmill or completed stair climbing as interruptions to sitting. The uninterrupted sitting participant remained seated throughout the seven-hour period. The participant for interrupted sitting with light intensity activity walked on a treadmill at 3.0 $km.hr^{-1}$ for two minutes and for the interrupted sitting by vigorous physical activity, participant performed stair climbing using the StairMaster 7000 at 60 $steps.min^{-1}$ for two minutes. Walking at this speed requires approximately 2 METs (Ainsworth et al., 2011). Climbing at this speed required 8.7 ± 0.6 METs in a young, aerobically fit sample (Eves & White, unpublished), similar to the expenditure of 8.6 and 8.8 METs reported by Bassett et al. (1997) and Jetté et al. (1990) respectively.

Participants remained seated in between breaks and were only allowed to perform sedentary activities such as watching TV or movies, doing work on a laptop or reading books, and newspapers. Participants were advised to minimise their interaction had they known each other or vice versa. A wheelchair was used to transport participants to the toilet to minimise energy expenditure used other than exercise trials. Total plain water at libitum was recorded for each participant during each session to maintain the same amount of intake throughout each intervention as employed in Dunstan et al. (2012).

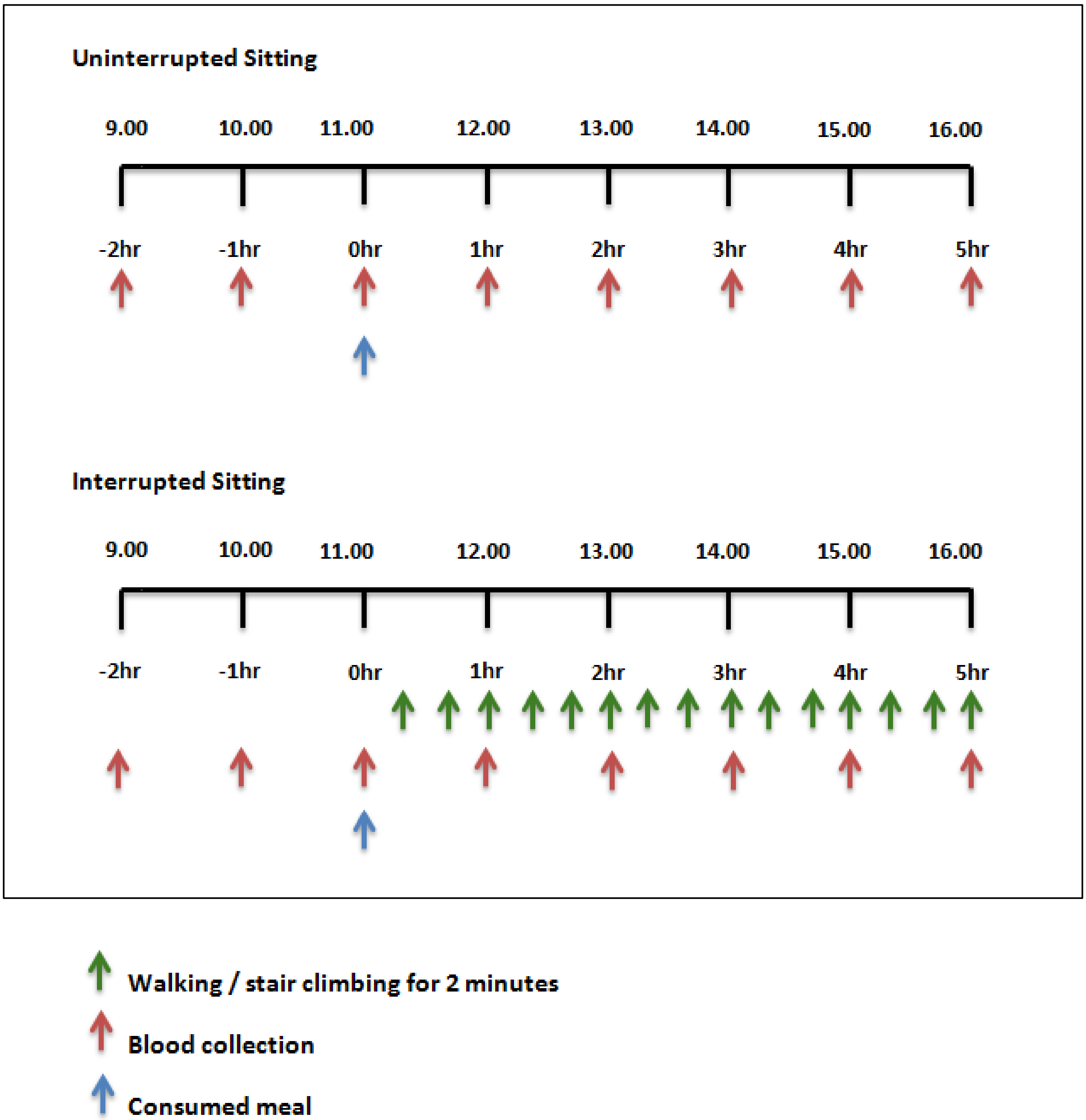

Figure 4.2 Flowchart of study protocol.

b) Blood samples analyses

Serum analyses were performed in duplicate using semi-automatic spectrophotometric clinical chemistry analyser, Instrumentation Laboratory (ILab 650, Cheshire, UK) to measure the concentrated glucose, triglycerides (TG) and non-esterified fatty acid (NEFA).

Ethical approval

Ethics for this study was approved by the Science, Technology, Engineering and Mathematics Ethical Review Committee, University of Birmingham with ethics reference number ERN_16_0472.

Data reduction and statistical analysis

To evaluate the changes of the variables in response to the test meal, the area under the curve (AUC) was calculated using the trapezoidal formula. To allow comparison with previous research (Dunstan et al., 2012), AUC for two hours postprandial as well as AUC for the five-hour period were calculated. In addition, many metabolic processes when plotted over time are characterised by relatively simple shapes. For example, any systematic increase over time, e.g. the triglyceride response to a test meal, results in a linear function. Any changes that increase to a peak and then decrease towards pre-meal baseline, e.g. glucose, are characterised by a quadratic function reflecting the curvilinear nature of the response to the meal. If the peak response occurs asymmetrically within the time window, e.g. glucose peaking at two hours within a five-hour window, then a cubic function may also present. To test for differences in these shapes between conditions, orthogonal polynomial trends across time were computed for the linear, quadratic and cubic components and the resulting polynomials were analysed (Hurren et al., 2011). One advantage of orthogonal polynomials is that they allow independent tests of the different components of the resultant response postprandially. A primarily peaked response, i.e. quadratic function, may not return to pre-meal levels resulting in an additional linear function over time.

Data were analysed using the SPSS statistical package for Windows, version 20.0. Shapiro-wilk's test for normality showed $p > .05$ and visual judgment of the histogram, Q-Q plots and boxplots showed that the concentration of glucose and NEFA were approximately distributed with skewness within the range of ± 1.96. A natural log transformation was applied to TG levels to improve the normality of their distribution. Preliminary analyses revealed no significant effects of sex, age or BMI on response to the test meal. Formal analyses employed repeated measures ANOVAs, and the associated orthogonal polynomials, to test for differences between conditions. We predicted an ordered relationship such that uninterrupted sitting > light walking > stair climbing based on the different intensities of the activities (linear polynomial across conditions). The Greenhouse-Geisser epsilon correction was applied to the degrees of freedom. Follow-up analyses compared the conditions using studentized range post-hoc tests unadjusted for multiple tests to facilitate comparison with Peddie et al. (2013).

4.4 Results

The table below summarises the mean for age, weight, height and BMI for 24 participants involved in the study (Table 3.1). As can be seen, participants had a BMI of 31.06 ± 3.96 in obese class I (WHO, 2000). All participants would be classified as obese (BMI ≥ 31.06).

Table 4.1 Participant characteristics (n = 24).

Variables	Mean (SD)
Age	32.17 (5.57)
Weight (kg)	85.34 (14.52)
Height (cm)	165.05 (9.09)
BMI	31.06 (3.96)

Table 4.2 Values of metabolites prior to the test meal.

Variable	Mean ± SD ($mmol.L^{-1}.hr^{-1}$)		
	Sitting uninterrupted	**Walking**	**Stair climbing**
Glucose	4.38 (0.55)	4.26 (0.38)	4.23 (0.32)
TG	1.32 (0.69)	1.19 (0.78)	1.22 (0.58)
NEFA	0.84 (0.33)	0.79 (0.21)	0.78 (0.23)

As shown in Table 4.2 above, repeated measures ANOVA was employed and there were no differences found between the conditions pre-meal (all $p > .12$).

Glucose

Figure 4.3a below displays the pattern of glucose concentrations at one hour intervals throughout the seven-hour sessions. As can be seen, glucose increased immediately after meal and reached its peak at two hours postprandially (Figure 4.3a).

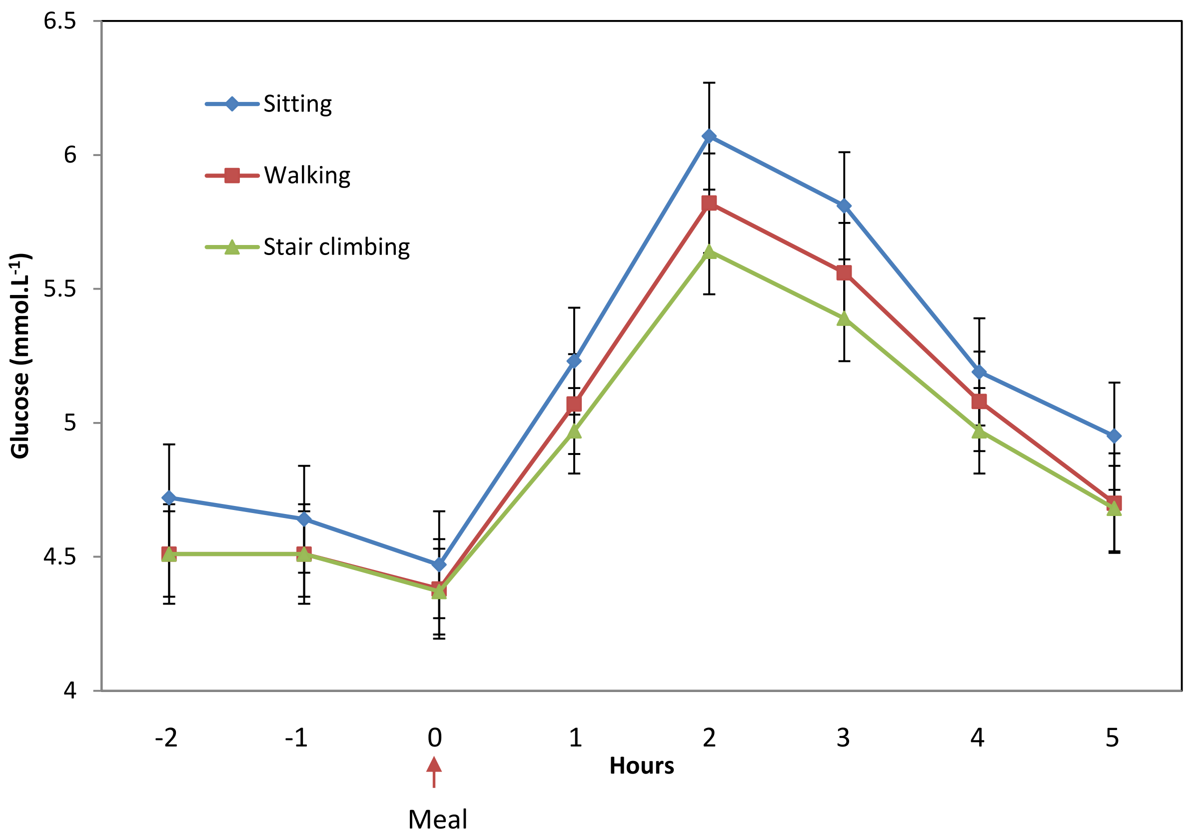

Figure 4.3a Glucose concentrations throughout the sessions.

To reiterate, an ordered relationship across conditions was predicted such that uninterrupted sitting > light walking > stair climbing based on the different intensities of the activities. The test of this ordered relationship would be the linear polynomial across conditions.

Analysis of the data from the immediate pre-meal values to five hours later, revealed a main effect of time ($F_{(3,\ 60.8)} = 51.92$, $p < .01$) that was described primarily by significant quadratic ($F_{(1,\ 23)} = 103.80$, $p < .01$; 63.6% of the variance) and cubic components ($F_{(1,\ 23)} = 65.74$, $p < .01$; 32.3% of the variance), with a significant interaction between the quadratic component and condition ($F_{(1,\ 23)} = 5.05$, $p = .04$). Follow-up analyses revealed differences in the quadratic component between uninterrupted sitting and stair climbing (p = .04) reflecting the lower peak response with stair climbing. There were no differences between the conditions for the cubic component over time ($F_{(1, 23)}$ = 0, 94 p = .34). In addition, the omnibus ANOVA contained a significant linear component over time ($F_{(1, 23)}$ = 6.97, p = .02; 2.7% of the variance) which did not differ between conditions ($F_{(1, 23)}$ = 2.13, p = .16).

Table 4.3 summarises the AUC for glucose, NEFA and TG measured for the conditions of uninterrupted sitting, walking and stair climbing. As NEFA yielded a negative AUC due to the postprandial decrease, a change in concentration was calculated and subtracted from the level just before the meal to test the reductions postprandially. The actual level is shown in the table.

Table 4.3 Area under the curve for glucose, NEFA and TG.

Variable	Mean ± SD (mmol.L^{-1})		
	Sitting uninterrupted	**Walking**	**Stair climbing**
2-hour test			
Glucose	5.65 (1.40)	5.44 (0.82)	5.30 (0.52)
TG	1.64 (0.87)	1.45 (0.89)[a]	1.46 (0.63)
NEFA	0.42 (0.15)	0.44 (0.017	0.38 (0.11)
5-h test			
Glucose	5.41 (0.99)	5.24 (0.52)	5.12 (0.44)
TG	2.25 (1.11)	1.95 (1.21)[a]	2.01 (0.94)
NEFA	0.28 (0.10)	0.32 (0.12)	0.30 (0.09)

[a] significantly different from uninterrupted sitting.

For analyses of glucose AUC, a marginally significant linear polynomial over conditions ($F_{(1, 23)}$ = 3.22, p = .09) was suggestive of an ordered relationship between the means for the five-hour period. Follow-up analyses suggested a smaller AUC for stair climbing than uninterrupted sitting (p = .09) which would be significant with one tailed probability for the predicted effect. Similarly, a marginally significant linear polynomial for the two-hour AUC ($F_{(1, 23)}$ = 4.14, p = .05) was consistent with a smaller AUC for stair climbing than uninterrupted sitting (p = .06).

Triglycerides

Figure 4.3b displays the pattern for TG concentrations at one hour intervals throughout the seven-hour sessions. As can be seen, there was a steady increase postprandially in all three conditions.

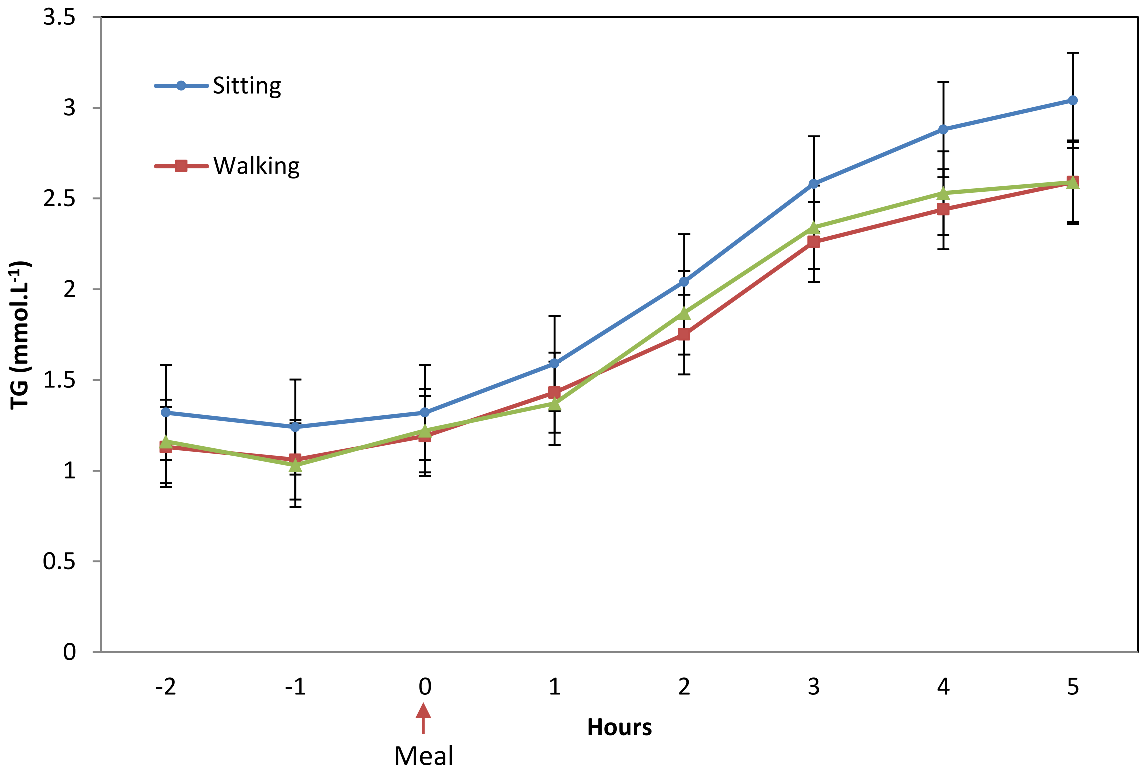

Figure 4.3b Triglycerides concentrations throughout the sessions.

Analysis of the immediate pre-meal and post-meal values revealed a main effect of time ($F_{(2, 51.5)}$ = 177.65, p < .01) that was described primarily by a significant linear component ($F_{(1, 23)}$ = 297.62, p < .01; 93.4% of the variance), with a suggestion that this differed between conditions ($F_{(1, 23)}$ = 3.13, p = .09). The response also contained significant quadratic ($F_{(1, 23)}$ = 40.00, p < .01; 5.1% of the variance) and cubic components ($F_{(1, 23)}$ = 16.95, p < .01; 1.0% of the variance) which did not differ between conditions (both p > .37). In addition, the ANOVA contained a main effect of condition ($F_{(2, 41.6)}$ = 3.99, p = .03). In follow-up analyses, there was a smaller response for light walking than uninterrupted sitting (p = .02), with a suggestion of a comparable difference for stair climbing (p = .09).

For analyses of the TG AUC, a significant main effect of condition ($F_{(2, 46)}$ = 4.08, p = .02) was accompanied by a marginally significant linear polynomial ($F_{(1, 23)}$ = 3.28, p = .08), suggestive of an ordered relationship between the means for the five-hour period. Follow-up analyses revealed smaller magnitude AUC for light walking than sitting (p = .02) with a suggestion of a similar difference with stair climbing (p = .08). For the two-hour AUC, a significant main effect of condition ($F_{(2, 43.5)}$ = 3.59, p = .04) was accompanied by a significant linear polynomial across conditions ($F_{(1, 23)}$ = 7.16, p = .01). Follow-up of the main effect of condition revealed that light walking differed from uninterrupted sitting (p = .04).

NEFA

Figure 4.3c displays the pattern for NEFA concentrations at one hour intervals throughout the seven-hour sessions. For NEFA, the level dropped postprandially as expected, with a lowest point reached two hours after the meal.

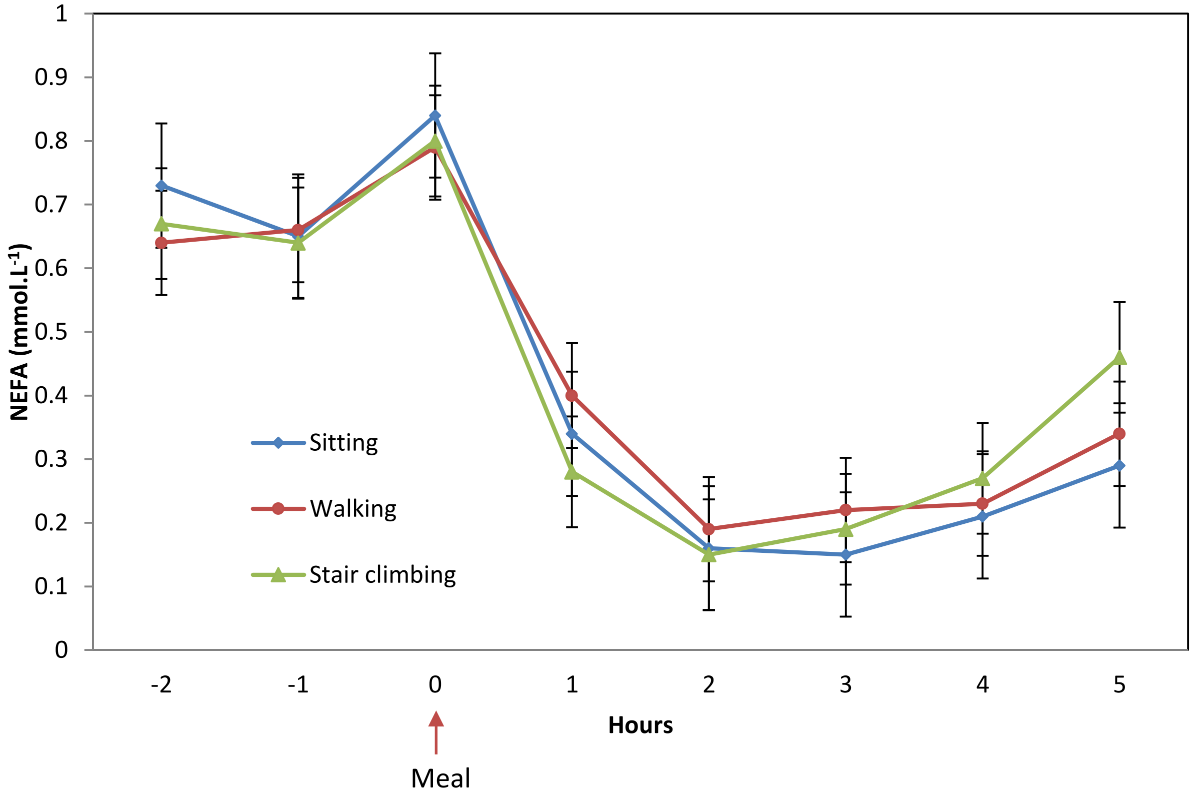

Figure 4.3c NEFA concentrations throughout the sessions.

Analysis of the immediate pre-meal value to five hours later, revealed a main effect of time ($F_{(2,\ 48.6)}$ = 105.62, p < .01) that was described primarily by linear ($F_{(1,\ 23)}$ = 81.29, p < .01; 31.6% of the variance) and quadratic components ($F_{(1,\ 23)}$ = 163.23, p < .01; 63.2% of the variance), with a cubic component that explained less variance ($F_{(1,\ 23)}$ = 49.09, p < .01; 4.8% of the variance). There were significant interactions between condition and both the linear

($F_{(1, 23)}$ = 17.86, p < .01) quadratic components ($F_{(1, 23)}$ = 4.71, p = .04). Follow-up analyses for the linear component revealed differences such that stair climbing was of smaller magnitude than uninterrupted sitting (p < .01) and light walking (p = .02). Similar differences between conditions occurred for the quadratic component but in this case stair climbing was of greater magnitude than uninterrupted sitting (p = .04) and light walking (p = .04). There were no differences between the conditions for the cubic component over time ($F_{(1, 23)}$ = 0.24 p = 0.63). Inspection of the graph suggests that the NEFA response with stair climbing returned more rapidly towards pre-meal levels after two hours of post-meal.

For the NEFA five-hour AUC, there were no significant differences between conditions (condition linear $F_{(1, 23)}$ = 2.86, p = .10). Similarly, for the two-hour AUC, there was only a marginally significant main effect of condition ($F_{(2, 40.7)}$ = 2.60, p = .09) suggesting equivalent reductions over two hours postprandially.

4.5 Discussion

In summary, as with much of the previous literature, a mixed pattern was seen in this study. For triglycerides, light intensity walking significantly reduced concentrations postprandially, with only suggestive evidence of a similar effect for the more intense activity of climbing stairs. For glucose, the evidence was reversed. Stair climbing lowered the postprandial peak compared to sitting, with no significant effects of light intensity walking, contrary to Dunstan et al., (2012). Nonetheless, stair climbing did not have a significantly greater effects than light walking as predicted. For NEFA, stair climbing resulted in a more rapid return towards pre-meal values than uninterrupted sitting and light walking but unlike Henson et al. (2015)

there was no attenuation of NEFA reductions postprandially with light walking. Overall, the data do not confirm the hypothesis of greater effects, the more intense the physical activity used to interrupt sitting (Larsen et al., 2017).

As outlined in the introduction, light intensity walking reduced postprandial glucose in healthy individuals (Bailey & Locke, 2015; McCarthy et al., 2017; Pulsford et al., 2017) and in those who were overweight/obese (Dunstan et al., 2012; Henson et al., 2015). In contrast, light intensity walking here had no effect on glucose in a sedentary overweight/obese sample of comparable size to Dunstan and co-workers original study. One possible explanation is that the relative young, lower risk sample here (32 years; fasting glucose 4.29 $mmol.L^{-1}$) compared to Dunstan and co-workers (54 years; fasting glucose 5.03 $mmol.L^{-1}$) may have had greater levels of cardio-respiratory fitness consistent with their demographic differences. Typically, cardio-respiratory fitness declines with age (Allied Dunbar National Fitness Survey, 1992) as does glucose control (Cowie et al., 2006). Further, BMI and cardio-respiratory fitness confer independent effects on glucose control (Lee, Sui, Church, Lee, & Blair, 2009). McCarthy and co-workers have demonstrated reduced effects of light intensity walking in fitter individuals relative to less fit participants. Without fitness data, there is no evidence for this potential explanation of the discrepancy between effects of light walking here and Dunstan et al. (2012). In contrast, the vigorous activity of stair climbing reduced postprandial glucose, consistent with the effects of walking at moderate intensity in both Peddie et al. (2013) and Dunstan et al. (2012).

As with other metabolic variables, results for the effects of interruptions to sitting on triglycerides postprandially have been mixed. Neither Thorp et al. (2014) nor Benatti et al. (2017) reported any effects of standing on triglycerides in overweight/obese and healthy samples respectively. In contrast, a combination of light walking and standing under free living conditions reduced triglycerides in elderly diabetic individuals the next day (Duvivier et al., 2017). Consistent with the latter study, walking at light intensity (Miyashita et al., 2013) and moderate intensity (Miyashita et al., 2015) reduced postprandial triglycerides in healthy men and an older sample of healthy post-menopausal women respectively. The reductions in triglycerides with light walking in this study are consistent with two previous studies. What is surprising, is that the more intense activity of stair climbing did not have a similar effect. Nonetheless, Peddie et al. (2013) also reported no differences between intermittent brisk walking and uninterrupted sitting; it was only the continuous 30-minute bout prior to the meal that reduced triglycerides postprandially. Concerning intensity, Durstine et al. (2001) noted that the intensity of exercise had a dose response relationship with blood lipids; the greater intensity of physical activity, the greater the reduction in triglycerides. Reasons for a reduced response in triglycerides for walking instead of stair climbing are unknown.

Some comment on the differences between analyses based on the AUC and those based on orthogonal polynomials is appropriate. As noted in the methods, changes in biochemical variables have characteristic shapes over time. An overall increase would result in a linear component whereas a peak within the time window would be reflected by a quadratic component. These separable aspects of change over time with polynomials allow independent tests of each aspect of shape in the response. For triglycerides, the consistent increase postprandially was reflected in a substantial linear trend (93% of variance). Both AUC and the linear polynomial analyses concurred that light intensity walking reduced triglycerides postprandially in this data set. In contrast, the glucose response was primarily quadratic in shape (63.6% of the variance). The peak response in the quadratic polynomial was smaller with stair climbing than uninterrupted sitting; there were no AUC differences. For NEFA, statistically similar AUCs contrasted with significant polynomial differences between stair climbing and the other conditions. An AUC provides a single estimate of change over time yet for the glucose polynomials, a substantial cubic component (32.3% of variance) reflected the asymmetrical change as glucose peaked at two hours within a five-hour window. Neither this cubic component nor the minor linear one (2.7% of the variance) differed between conditions. In essence, the glucose AUC included 35% of the variance for glucose change which did not differ between conditions. These two components simply added noise to the glucose AUC. In this study, polynomials were more sensitive to visible differences over time for glucose and NEFA. Orthogonal polynomials may provide a plausible alternative analysis for changes over time that characterizes metabolic responses.

4.6 Strengths and limitations

This study is the first to compare the effects of uninterrupted sitting and interrupted sitting with intermittent breaks of light intensity walking and vigorous intensity stair climbing in the laboratory setting. Previous experimental studies on breaking up prolonged sitting investigated on cardio metabolic markers in comparison between intermittent physical activity of light intensity and moderate intensity walking (Dunstan et al., 2012; Larsen et al., 2012), or standing and light intensity walking (Bailey & Locke, 2015; Henson et al., 2015). This study also pioneered the findings on non-esterified fatty acids following intermittent vigorous stair climbing for two-minute bouts every 20 minutes.

As for study limitations, the absence of estimates of cardio-respiratory fitness data might have explained the differences between this study and that of Dunstan and co-workers. Further, we did not formally assess physical activity during the conditions that would have confirmed differences in the intensity of the interruptions to sitting. Nonetheless, we are confident of difference between the conditions. Participants were monitored throughout the sessions and a wheelchair used to convey them to the toilet. Apart from that, we did not provide the participants' meals 24 hours prior to the testing session. The food diary was given to the participants to record their food intake to assure similar meals were maintained prior to each testing session. However, their compliance might have been compromised. Participants were reminded to maintain their normal physical activity required for daily living and kept them at minimal. However, we did not provide them with physical activity diary to observe their adherence towards the reminders. Finally, it is possible that in some way, group-based testing added noise to the data.

4.7 Conclusion

The study tested the effects of the intensity of short bouts of physical activity as intermittent interruptions to sitting. Light intensity walking improved triglycerides whereas vigorous intensity stair climbing improved glucose and NEFA when compared to sitting uninterrupted. Analyses based on orthogonal polynomials were more sensitive to changes than those using the AUC. It is possible that the failure to find consistent effects of the intensity of the interruption reflected a lower risk sample here than in previous research (Dunstan et al., 2012; Larsen et al., 2017).

This study could be a stepping stone for future research to determine the therapeutic intensity, duration and frequency of stair climbing for optimal health benefits in accumulated bouts especially at the workplace among sedentary employees. This study also shows that stair climbing can be integrated to break sedentary behaviour in order to have healthier lifestyle as it improves the level of blood glucose and triglycerides when compared to sitting uninterrupted. Apart from that, the study protocol can be applied to different target groups to compare the outcomes.

4.8 Recommendations

The outcomes from one-day intervention of uninterrupted sitting and interrupted sitting with light intensity walking and vigorous stair climbing could not be generalised to long term exposure. Future research needs to design for a longitudinal study to assess on the long term outcomes. This study did not apply the actual scenario for prolonged sitting at work as for instance, the participants were forced to sit and only allowed to read newspapers, books, doing work on their laptops or watching movies during the whole testing hours. They even were transported to the toilet using a wheelchair. In real situation, employees might need to answer phone calls, do photocopies and even walk to the toilet or rush to a meeting room. This could be applied in the future by allowing normal daily routine among sedentary staff at work provided that they need to wear a device to actually detect their bodily movements/change of posture that can precisely count their sedentary time or behaviour. It is recommended to provide meals to the participants the day before the trial takes place. This is to assure same amount of calorie intake are consumed to avoid any discrepancies to the physiological effects data. Finally, the trial could be arranged as individual-based testing to minimise any errors while handling the session, thus reduces the noise to the data.

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CHAPTER 5

GENERAL DISCUSSION

This chapter summarises findings from the three intervention studies tested in this thesis. The thesis provides an insight into the potentials of stair climbing intervention that may influence healthier lifestyle among sedentary employees. The first study of the thesis tested the effectiveness of weight loss messages displayed on posters as point-of-choice prompts. The design aimed to test mechanisms underlying habit development and the potential interaction with the height of the climb proposed. Unfortunately, there were no effects of intervention on electricity usage to provide information on the questions posed in the study. Disappointingly from a workplace standpoint, a health promotion message was not able to reduce electricity consumption, a potential hook to enage businesses in these simple health promotion interventions. The second intervention study held in the field replicated studies by Boreham et al. (2005; 2000) but with modifications to the height of the climb (four instead of eight floors) and the number of daily ascents (eight vs. six). In addition, a prompt was delivered to individuals who wished to improve their health. Four-floor climbs, eight times a day proved feasible and had similar effects to the eight-floor climbs in Boreham et al. (2000) on lipoproteins. There was some evidence of increased automaticity of instigation habits in response to the prompt. The physiological outcomes shed light the therapeutic frequency that may yield benefits in physiological markers. This result is important as the four-floor climb required approximately two minutes for completion and represented relatively brief interruptions to work. The laboratory setting trial of intermittent interruptions to sitting was novel. To date, little is known about the impacts of intermittent short bouts of the vigorous activity of stair climbing in comparison with light intensity physical activity and uninterrupted sitting. We predicted greater effects, the more the intense the interruption. The findings were mixed, consistent with much of the previous literature on interrupted sitting interventions in laboratory settings. While light intensity walking improved postprandial triglycerides, the more intense interruption of stair climbing did not have an equivalent effect. In contrast, stair climbing reduced the glucose peak postprandially and attenuated NEFA reductions whereas light intensity walking did not have similar effect when compared to uninterrupted sitting.

5.1 Stair use measurement during intervention

Various studies reported on stair use intervention either in shopping malls (Kerr, Eves, & Carroll, 2001c; Webb & Eves, 2005), train stations (Boen et al., 2010; Iversen et al., 2007), university buildings (Howie & Young, 2011; van Nieuw-Amerongen, Kremers, de Vries, & Kok, 2011) as well as workplaces (Eves & Webb, 2006; Kerr, Eves, & Carroll, 2001). Different methods were used to measure stair use. Self-reported on stair use based on the frequency and number of floors climbed per day within a typical working week was employed by Engbers, Poppel, & Mechelen (2006) among government employees from two selected worksites. The calculation for self-reported frequency involved multiplying the average number of stair use bouts per day with number of working days in a week. As for the self-reported number of floors climbed in a week equals to number of floors climbed per day multiplied by frequency of stair use in that particular working week. In another self-reported data on stair use, modified questionnaire from Community Health Survey (2010) was used and adopted to suit the workplace intervention among city employees in New York City. One of the question used to assess stair use at work was '*In the last month, how frequently did you use stairs at work?*'. The self-reported data was used to observe any associations between workplace design and point-of-choice prompts towards stair use among employees (Ruff et al., 2014).

Objective measurement of stair use was done by placing the infrared beam counters to count the number of people use the stairs (Olander & Eves, 2011b). However, these automated counters could not assess on an individual level and made it impossible to observe any associations between stair use behaviour with sociodemographic factors or individual characteristics. Thus, this method was only limited to measure the frequency of stair use. In addition to these automated counters, Engbers and colleagues used a hand's free device with an antenna that was placed behind the door to the staircases. This device could detect any individuals within the range of 70 to 100 cm. Each participant was given a chipcard that functioned as an identifier. A record on time, date and the floor that each participant entered and exited using the staircases were stored in the system (Engbers, Poppel, & Mechelen, 2006).

The monitoring of stair use was also done by using a video recorder to tape the direction of stair use either ascent or decent, individual's sex and weight status. The latter was coded using the outline image of the individual which appeared on the computer screen. The finding from a study that used this method showed that stair use was greater among overweight individuals (Eves et al., 2006). Another method to measure stair use was by direct observation i.e. via placement of an observer (Kwak et al., 2007; Lee et al., 2012; Olander & Eves, 2011a). Observers could be visible or positioned inconspicuously to assess the stair use in terms of frequency and method of ascent (in presence of lifts or escalators).

5.2 Point-of-choice prompt vs. contextual variables

Giving the evidence of lower effectiveness of workplace interventions than in public access settings (Eves & Webb, 2006; Nocon et al., 2010), the first intervention was tested in one of the university buildings, Mason Hall. The aim of the intervention was to test the effectiveness of message displayed as a point-of-choice prompt for the residents to use stairs instead of the lifts to reach their destination. In a quasi-experimental design, previous exposure to context prior to the intervention was manipulated. Prior development of lift usage habits may impede worksite effects. The message focussed on weight loss following consistent stair use to the topmost level of the building. The message did not improve stair usage as the findings revealed no significant changes to the total electricity used. Lifts usage remained unchanged by the intervention.

Students usually carry backpack with books and stationery to class. Travellers and pedestrians carrying heavy backpacks report exaggerated steepness in explicit awareness (Eves, 2014; Proffitt, 2006). They tended to perceive stairs as steeper and avoid stair climbing. Additionally, the exhaustion after a long day at the university and walking back to the residence could have enhanced the decision to use the lifts as fatigue would exaggerate the slant estimation of the stairs (Taylor-Covill & Eves, 2013). Moreover, not all the students had their rooms on the highest level of the building. Thus, the message that calculated total calories burned if they reached the top floor may not have interested residents who were living on the lower floors. Although the posters affixed to the notice board adjacent to the lifts and walls were typically seen to be visible and noticeable, the feeling of not being related to the content of the posters and feeling of laziness (Kerr, Eves, & Carroll, 2001a) could be plausible causes of stair avoidance. Kerr et al. (2001a) also reported that the higher number of people using the lifts contributed to the lesser number of people opted for the stairs. In agreement, students often walk in groups. Any member of the group who chose to use the lift could influence other members to follow their decision.

Escalators in shopping malls and train stations are generally available at all times whereas lifts at the worksites on the other hand required waiting time to be available for use. Moreover, there was only one lift provided for each block and the lift was facing the stairwells. For the crowd in the morning with only one lift available, the stair use definitely could increase irrespective of signage (Olander & Eves, 2011b). People don't like to wait especially when they are in a rush. For example, a delay in opening of the lift's door reduced the number of persons using the lift (Houten, Nau, & Merrigan, 1981) and increased stair usage. Generally, the effects of posters were more prominent in escalator settings but less effective when applied to lift settings (Nocon et al., 2010). This was expected as reported by Eves (2010) when comparing the choice between stairs and lifts, and between stairs and escalators, greater change of stair climbing activity was observed in the latter. The options between stairs and lifts revealed only weak evidence of successful stair climbing interventions even though there was an encouraging pattern of stair use, i.e. descent (Eves & Webb, 2006).

The stair climbing intervention at the students' residence only used posters as the point-of-choice prompt. Similar approach by some other studies held in the university buildings had shown significant improvement in stair climbing activity (Bungum, Meacham, & Truax, 2007; Lee et al., 2012; Olander & Eves, 2011a; Russell, Dzewaltowski, & Ryan, 1999); no effects were recorded for this intervention. Additional components to the intervention such as stair risers (Eves, Olander, Nicoll, Webb & Eves, 2005), art and music (Boutelle, Jeffery, Murray, & Schmitz, 2001) and interactive stairwells environment (Swenson & Siegel, 2013) could possibly increase stair use among the residents if it is to be repeated in the near future. In agreement, greater improvement of stair use at worksite were reported when combination of motivational and directional signs were displayed (Jennings, Yun, Loitz, Lee, & Mummery, 2017).

The intervention was performed twice in spring and autumn term time. The same posters as point-of-choice prompts were used. Considering they had the first exposure in the earlier term time, autumn, repeated intervention could have created a new sustainable habit (Bellicha et al., 2016). However, there was no evidence of habit development in autumn or spring. The possible underlying reason for this could be due to different student's cohorts who accommodated in the residence.

Perhaps, this study could generate positive outcomes on the electricity consumption if several improvements are made; 1) the term time of subsequent year is the same if to be repeated for the different cohort, 2) study is performed at the higher university buildings with signage on each floor as the difference of energy usage for travel of greater distance could be more notable, 3) point-of-choice poster should be accompanied with additional intervention component such as stair riser banners or visual enhancement of the stairs to increase motivation and visibility respectively, 4) target group is relatively older individuals than the students who might have more desire to improve health and lifestyle, overweight individuals were reported to be more affected by the intervention (Eves et al., 2006; Lewis & Eves, 2011), 5) other demographic factors such as sex, education level, income level and occupation should be taken into account, and 6) the observation between the interventions should be kept regular to assess the consistency of stair climbing usage after the removal of the posters.

5.3 Stair climbing for sedentary employees

As the thesis focussed on the worksite interventions, the second intervention involved sedentary employees of the same university asked to climb four floors of stairs eight times.day^{-1} during weekdays. A health prompt was used prior to stair climbing that appeared on the employee's desktop monitor. The aim was to reduce prolonged occupational sitting that could jeopardise health. Continuous climbing of four floors hourly was hoped to become a habit in changing the unhealthy behaviour of prolonged sitting. As participants were asked to climb eight times.day^{-1} consistently for eight weeks, a higher number of repetition of stair climbing in response to the cue was expected to increase the strength of habit development (Lally, Wardle, & Gardner, 2011). Consistent repetition of stair climbing across the day for eight weeks, with the exception on weekends, would involve 320 cues, sufficient for automaticity even with missing one climb would not affect the process of habit formation (Lally, van Jaarsveld, Potts, & Wardle, 2010). Surprisingly, 62% of UK office based workers reported stair climbing as their occupational physical activity habit during office hours (Smith et al., 2018). This recent finding tallied with the statement by majority of the participants (87.5%) that the stair climbing activity was convenient and easy to incorporate throughout office hours. In the current intervention, the automaticity of response to the prompt cue to perform stair climbing was increased but did not reach asymptote to declare that habit of stair climbing had completely developed among the participants. This could be due to the relatively small sample size that possibly was unable to reliably measure habit development. Thus, if to be repeated, sample size must be larger and able to generalise to the population.

Continuous stair climbing of four floors was shown to improve glucose and lipid profiles of the participants. Significant reductions of LDL-C, TC and TC/HDL-C ratio would have lowered the risk of CHD (Leon & Sanchez, 2001) and IHD (Lemieux et al., 2015). Mortality rates was reported as lower in individuals who regularly performed stair climbing activity (Lee & Paffenbarger, 2000). Stair climbing used more energy than per minute jogging. Teh & Aziz (2002) estimated gross energy needed for stair ascent in the field was 9.6 METs. Thus stair climbing was categorised as vigorous intensity physical activity. Physical activity that required more than 6 METs has been linked to reduce risk of CHD (Lakka et al., 1994; Lee, Sesso, Oguma, & Paffenbarger, 2003; Sesso, Paffenbarger, & Lee, 2000; Tanasescu et al., 2002; Yu, Yarnell, Sweetnam, & Murray, 2003). CVD risk reduces more in vigorous than moderate physical activity (Lear et al., 2017) and the reduction of LDL-C, TC and TC/HDL-C ratio from regular stair climbing activity as reported in this thesis could reduce the risk of CHD (Arsenault et al., 2009). A study by Morris, Clayton, Everitt, Semmence, & Burgess

(1990) on male employees taking vigorous aerobic exercise at least twice a week had shown to reduce 50% of the risk of getting CHD. Similarly, the CHD risk was also reduced after consistent high intensity physical activity performed by Finnish adults more than 2.2 hours.week^{-1} (Lakka et al., 1994). With the accumulation of two minutes for each completed climb performed by the participants in the current thesis, with the sum of 64 minutes.week^{-1}, stair usage could be a vigorous physical activity of choice since it is easier to complete. Stairs are found abundantly at work, do not need proper facilities or supervision and can be performed at any time without restrictions. Moreover, it was reported that MVPA accumulated in less than 10 minutes bouts yielded similar reduction in plasma TG, waist circumference and BMI as those bouts of 10 minutes or more (Glazer et al., 2013). MVPA regardless of how it is accumulated either in bouts or sporadically showed similar health benefits and reduced mortality risk (Saint-Maurice, Troiano, Matthews, & Kraus, 2018).

Concentration of fasting blood glucose in the circulation was also improved after the intervention. Frequency of structured stair climbing activity was shown to produce beneficial effect of fasting glucose. Maintaining the frequency of physical activity was crucial to sustain the glucose equilibrium in the body. While individuals are performing exercise or any physical activity, the contracting skeletal muscle increases the rate of glucose uptake from the circulation (Richter, Derave, & Wojtaszewski, 2001). Plasma glucose supplies between 20 to 50% of total energy during physical activity and with increase in intensity and duration, a greater glucose utilisation by the muscle fibres (Coggan, 1991). The fasting glucose in the current study showed significant improvement as measured within 24 hours post-intervention, although at baseline, the concentration of glucose was within the non-diabetic value. Hence, stair climbing would be another option of vigorous physical activity for patients with pre-diabetes or type 2 diabetes, as stated by Hordern et al. (2012) as these groups will need a minimum of 125 minutes of MVPA per week. Here, stair usage with, on average, 64 minutes of accumulated activity each week reduced fasting blood glucose.

5.4 Stair climbing in cumulative bouts

As cumulative bouts were reported to be as effective as one session of continuous physical activity (Magutah, Meiring, Patel, & Thairu, 2018), the third intervention compared effects of short bouts of light intensity walking and vigorous stair climbing on blood glucose, lipid profiles and NEFA concentration. In the laboratory setting, participants were scheduled for three of seven-hour sessions, each session with different physical activity: 1) uninterrupted sitting, 2) interrupted sitting with two minutes of walking at 3.0 $km.hr^{-1}$ every 20 minutes, and, 3) interrupted sitting with two minutes of stair climbing at 60 $steps.min^{-1}$. Results revealed significant improvements in triglycerides for light intensity walking at two-hours and five-hours postprandially. Even though stair climbing was expected to yield greater improvement in blood glucose and lipid profiles, it seemed that the dose-response of this vigorous physical activity in the laboratory setting did not reach the required level. Dunstan et al. (2012) reported that both light intensity and moderate intensity walking for two minutes every 20 minute bouts showed significant reduction of glucose and insulin concentration. Nonetheless, there were greater effects of the moderate intensity walking. Similarly moderate intensity walking for one minute and 40 seconds every 30 minutes improved glucose and insulin (Peddie et al., 2013).

While there were no significant effects for the AUC analyses of blood glucose either two-hour and five-hour postprandially, the polynomial analyses were more encouraging. The current intervention showed a smaller peak glucose response postprandially for stair climbing than uninterrupted sitting. Nonetheless, this was a relatively healthy sample with blood glucose at baseline within the normal range. Different findings were reported when tested in diabetic participants. A study by Honda et al. (2016) on type 2 diabetic participants yielded a promising result on the postprandial glucose. Participants were asked to climb to second floor at 80-110 steps.min^{-1} and decent to the ground floor at preferred pace. They repeated the ascent and decent for six times. Time required was three minutes for each complete bout. Stair climbing exercise was scheduled at 60 and 120 minutes postprandially and blood collection was performed 30 minutes after exercise. Significant difference of blood glucose was found after exercise at two hours postprandially compared to resting for the whole three-hour session (Honda et al., 2016). Similarly, in another stair climbing exercise but with 12 repetitions of stair ascent (90-120 steps.min^{-1}) and decent (comfortable rate) in type 2 diabetics revealed greater reduction in blood glucose level than walking on a flat surface (Takaishi & Hayashi, 2015). Additionally, stair climbing was found to be more effective in reducing glucose postprandially in comparison to cycling (Takaishi & Hayashi, 2017).

Interrupted sitting with 1.5 minutes brisk walking on the treadmill every 15 minutes among post-menopausal women yielded 15% reduction in plasma triglycerides compared to eight hours of uninterrupted sitting (Miyashita et al., 2015). In contrast, interrupted sitting with light intensity of walking alone and walking plus moderate physical activity for two minutes every 20 minutes in healthy children and youth did not improve any cardio-metabolic markers (Saunders et al., 2013). However, the lower intensity of walking at 3.0 $km.hr^{-1}$ was shown to improve the AUC and linear polynomial for triglycerides among overweight adults in the current intervention, while stair climbing did not. As with other metabolic variables, results for the effects of interruptions to sitting on triglycerides postprandially have been mixed.

5.5 Stair climbing and its sustainability

An active prompt approach was used by installing a pop up reminder on participants' desktop. The message appeared hourly during weekdays. Repetition of stair climbing throughout eight hours of working period was expected to develop a healthy habit in reducing prolonged occupational sitting. Sitting behaviour is established especially among desk-based employees. However, as noted by Pedersen, Cooley, Mainsbridge, & Cruickshank (2018), the prompt was effective in changing unwanted behaviour such as prolonged sitting to wanted behaviour. Prompts by telephone (Conn, Burks, Minor, & Mehr, 2003) and emails (Dinger, Heesch, Cipriani, & Qualls, 2007; Dinger, Heesch, & McClary, 2005) had been also shown to increase exercise and walking respectively. It was noted that with more frequent occurrence of the prompt, greater improvement was observed (Lombard, Lombard, & Winett, 1995).

Minimum of 103 $climbs.week^{-1}$ with average of 20.6 $climbs.day^{-1}$ recorded for the eight-week intervention in the current study with an estimated of 41.2 minutes of time spent of not being sedentary with the aid of the prompt. The number of climbs was more on days when participants were not involved in meetings and other important tasks. The majority of the participants reported that would continue performing regular stair climbing after the intervention ended suggesting the possibility of this activity to sustain over a longer period of time. However, with equivocal results of stair climbing intervention at workplace (Bellicha et al., 2015; Jennings et al., 2017; Nocon et al., 2010), the sustainability has yet to be established. The use of point-of-choice prompt among white and blue collar employees was reported to decline following the removal of the prompt (Kwak, Kremers, van Baak, & Brug, 2007). Similar findings were observed in female employees, even with additional email sent to emphasise the benefits of stair climbing (Auweele, Boen, Schapendonk, & Dornez, 2005). Surprisingly, with additional footprints affixed to the floor, sustained stair use was reported after intervention (Hoecke, Seghers, & Boen, 2018). The difference in this study was that participants enrolled for health reasons, and individual prompts targeted those wishing to change.

In public access settings, with the aid of point-of-choice prompts, stair climbing was reported to be higher than baseline after removal of the signs (Blamey, Mutrie, & Tom, 1995; Kerr, Eves, & Carroll, 2001b; Lee et al., 2012; Puig-Ribera & Eves, 2010; Webb & Eves, 2007) and few studies reported failure to sustain the choice of stair use after intervention ended (Iversen, Händel, Jensen, Frederiksen, & Heitmann, 2007; Sloan, Haaland, Leung, & Müller-Riemenschneider, 2013). As habits are learned behaviours, developed from repetitions, initial process usually triggers by environmental stimulus. Thus, in order to routinely perform stair climbing, continuous reinforcement might be necessary to ensure the cues motivate stair use (Pedersen et al., 2018). For individuals trying to improve their health, successful health behaviour may act as reinforcement.

5.6 Strengths and limitations

The exploratory of message specificity on weight loss at the student residence in one of the university buildings could be the reference as this type of message did not yield any difference in lift usage. The mixture of A3 and A4 size posters seemed not to be adequate in size and perhaps should use an A1 size to increase visibility even though they were printed in colour. The stair climbing activity of the residents was not observed at the site. Thus the actual number of persons performed stair climbing during baseline and intervention could not be estimated. The habits of walking in group that influenced taking the lift to the upper level also could not be determined among the residents. There were six buildings involved and comprised in one location with different heights. If to be repeated, buildings should be selected randomly and dispersed in location and have more floors so that longer distance travelled by the lift would show greater difference if lift usage decreased during the intervention.

This thesis targeted employees at work and primarily introduced stair climbing activity to be incorporated during working hours and as interrupted sitting to increase number of breaks to avoid prolonged sitting. Integrating stair climbing using available stairs at work was promising with significant benefits to health. A total of four floors was lower than other stair climbing interventions at office buildings and gave advantages to the participants in terms of time to complete the climb and improved self-efficacy to consistently continue the activity for eight weeks. Stair climbing at work adapted prompt message as a reminder to perform the activity and measured the habit of automaticity that could develop among the participants throughout the intervention. However, small sample size of only eight participants in the experimental group yielded mixed evidence of habit development from the assessment of self-report automaticity behaviour index (SRBAI). The number of participants aims to be at larger scale and could be repeated at other worksite with availability of more numbers in buildings with at least four floors.

5.7 Conclusion and implication

In conclusion, this thesis determined that a point-of-choice prompt using weight loss focussed message did not alter electricity consumption in student accommodation. Workplace stair climbing was shown to improve fasting glucose, LDL-C, TC and TC/HDL-C ratio in a relatively small sample. This suggests that workplace stair climbing could reduce the risk of type 2 diabetes and CVD. Relative to uninterrupted sitting, intermittent two-minute bouts of stair climbing every 20 minutes reduced the postprandial glucose peak and attenuated reductions in NEFA. The findings reported in this thesis provide the groundwork for further worksite stair climbing interventions to promote healthy employees by reducing occupational sitting.

5.8 Recommendations for future research

Interventions involving university students need proper planning especially on the timing of the intervention as their availability at the campus depends on their term time. This population also comes from different cohorts and the involvement of which cohort to be the target group of the intervention must be clearly emphasised and justified. Do not use different cohort when assessing the development of habit as the findings could be compromised. The choice of the height of the buildings is very important. The use of buildings of four floors and above might generate a bigger difference between the energy consumption while the lifts are in used and during the standby mode. Do not leave the stairs unobserved throughout the intervention period. In circumstances whereby there is a shortage in human resources, placement of a video recorder to observe stair use during intervention would be a good option.

In order to develop appropriate intervention, patient and public involvement (PPI) is imperative. PPI ensures research to be relevant, of good quality, and participant friendly. Do listen to the opinions and experience of the research team and participants to improve the study design, tools used or the protocols applied in order to deliver the intervention effectively. As for this study, pre and post interview should be conducted among first year university students to gather the information on their lived experience regarding any health or physical activity interventions as well as their expectations to improve involvement process and to evaluate their feedback after the intervention for further improvement. The clarity and reflexivity are among the key factors of PPI to avoid absence of effects, inappropriate resources, and failure of the intervention.

As for the second study i.e. stair climbing at work, the selection of study sites is crucial. Do not choose area with limited number of acquired height of the buildings as this will restrict the number of volunteers and thus, randomised control trial can't be conducted. The sample size will be small and the findings can't be generalised to the population. Do not leave the sessions of stair climbing unattended. A placement of an observer or installation of a video recorder will be beneficial in assessing participants' adherence and fidelity of the intervention. Do arrange for a follow-up session to evaluate the sustainability of the intervention. Conduct an interview or focus group discussion to view their reasons or motivations pertaining to the sustainability.

To date, little is known about the health effects of stair climbing when employed as short two minute bouts at 60 steps.min^{-1}. Further adjustment to the stepping pace can be accustomed in other laboratory studies to determine the most effective intensity for stair climbing that would give greater impacts on health benefits. As the current intervention only showed effect of light intensity walking on triglycerides with no effects of stair climbing. The sample size with a total of 24 participants was adequate but further inclusion and exclusion criteria should be emphasised. Less healthy participants might have portrayed greater improvements after the intervention. For example, sampling could be done among obese class 1 and 2 participants with exclusion of overweight volunteers since individuals with greater body weight are most affected by the exercise. In addition, estimate of cardio-respiratory fitness would have improved the study. Even though a food diary was kept to assure the same meal was consumed the day before the testing, it would be beneficial if the meals for that day were prepared by the researcher and standardised prior to the three days of testing. For the meal given during the trial, do provide them in liquid form rather than solid foods or snacks. This will reduce the consumption time and participants would have extra few minutes before starting with the first physical activity after the meal. Similar goes for the physical activity or daily chores performed by the participants either at work or home prior to the testing to avoid any remnants of previous activities interfering with the exercise in the laboratory. Thus, periodic reminders are necessary and physical activity diary should be provided. And lastly, do not attempt to handle the trial sessions without assistants if they are conducted in a group-based testing. The role of the principal investigator and assistants should be clearly assigned to avoid any errors or delays during the trial sessions.

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Appendix 1

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CLIMBS at Work

Stair Climbing and Health Outcomes

Participant Information Sheet

Introduction
This is a PhD study and we would like to invite you to take part in our study. This study will take about 2 months to complete. It involves regular stair climbing while at work and its impact on health.

Location
This study will take place at School of Sport, Exercise & Rehabilitation Sciences, University of Birmingham and your normal place of work.

Investigators
Principle Investigator: Dr. Intan Suhana Munira Mat Azmi
Supervisor: Dr. Frank Eves

Purpose of the study
The purpose of this study is to assess the feasibility of regular stair climbing activity throughout office hours and to identify the effects of this workplace stair climbing on indicators of health such as cholesterol.

Research Procedure
Experimental group
1. Participants in the experimental group will need to climb stairs for four floors continuously on eight separate times during the day at work for eight weeks. A pop up message will be sent to you by your computer to remind you to perform the activity.
2. Blood samples will be taken before and after the intervention study to compare your metabolic and lipid profile. For these blood tests, you will need to fast overnight and attend the laboratory in the morning for about three hours on each visit.
3. In addition, we will measure your height and weight with a simple scale that you stand on.
4. We will also provide you with a pedometer to wear throughout the study. At the end of the study, we will give you information on the number of steps per day that you take.

Eligibility for the study
All participants will need to meet the following inclusion criteria:
- Office-based support workers with sedentary lifestyle
- Able to climb stairs without problems
- Healthy and not on medication

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W: www.bham.ac.uk

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Are there any risks?

Stair climbing exercise

You might experience tiredness and shortness of breath during stair climbing. However, these sensations will be temporary and will subside within few minutes after stopping the activity. Furthermore, you will not be asked to start climbing four foors of stairs at the beginning of the study since the number of stairs will increase gradually throughout the intervention period. You will be told to conclude your stair climbing activity with a cool-down period immediately after the last flight of stairs.

Blood sampling

You will feel very minimal discomfort during the blood withdrawal, however, the procedure is simple and will be performed by the qualified researcher.

Confidentiality

You will be allocated an ID number and your full name never obtained. This ID number will be written on the coded answer sheet during data collection. Only the Principal Investigator or research team members will have access to these data. The findings of this study will be presented in conferences, published in journals and books as well as be used as teaching purposes. No individuals will be identified in any publication.

Rights

It is your choice whether or not you wish to take part in this study. If you wish to take part in this study, you will be given this information sheet to read and be asked to sign a consent form. Requests for a copy of the results attained will be honored following study completion and publication in a peer-reviewed scientific journal.

Withdrawal

You are allowed to withdraw from this study at any time you feel uncomfortable or do not wish to continue. The deadline for withdrawal from the study is up to the last day of the fourth week of the study. You will be given a £50 shopping voucher upon completion of this study and be informed personally about the changes you have made towards your health outcomes at the end of this study.

If you wish to withdraw, there is a contact number provided on the information sheet to be called. Your data will not be retained after withdrawal and no compensation will be given.

Contact person

University of Birmingham Edgbaston Birmingham B15 2TT United Kingdom
W: www.bham.ac.uk

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If you have any complaints or query pertaining to this study, please contact the Research Supervisor as below:

Dr. Frank Eves
School of Sport, Exercise & Rehabilitation Sciences
College of Life & Environmental Sciences
The University of Birmingham
Edgbaston, Birmingham
B15 2TT
United Kingdom
Tel:
Email: f.f.eves@bham.ac.uk

If you wish to withdraw from the study or request a copy of research outcomes, please contact the Principal Investigator below:

Dr Intan Suhana Munira Mat Azmi
School of Sport, Exercise & Rehabilitation Sciences
College of Life & Environmental Sciences
The University of Birmingham
Edgbaston, Birmingham
B15 2TT
United Kingdom
Tel:
Email: imm339@bham.ac.uk

Thank you for your time. Your cooperation throughout this study is very much appreciated.

UNIVERSITY OF BIRMINGHAM

Stair Climbing and Health Outcomes

Consent Form

This information is being collected as part of a research project concerned with the effects of workplace stair climbing on the insulin system and blood lipids by the School of Sport, Exercise & Rehabilitation Sciences, University of Birmingham. The information which you supply and that which may be collected as part of the research project will be entered into a filing system or database and will only be accessed by authorized personnel involved in the project. The information will be retained by the University of Birmingham and will only be used for the purpose of research, and statistical and audit purposes. By supplying this information, you are consenting to the University storing your information for the purposes stated above. The information will be processed by the University of Birmingham in accordance with the provisions of the Data Protection Act 1998. No identifiable personal data will be published.

I confirm that I have read and understand the participant information leaflet for this study. I have had the opportunity to ask questions if necessary and have had these answered satisfactorily.

I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. If I withdraw my data will be removed from the study and will be destroyed.

I understand that my personal data will be processed for the purposes detailed above, in accordance with the Data Protection Act 1998.

Based upon the above, I agree to take part in this study.

Name of participant.............................Date............... Signature....................

Name of researcher............................ Date............... Signature....................

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W: www.bham.ac.uk

Appendix 3

The University of Birmingham

School of Sport and Exercise Sciences

General Health Questionnaire

Name: ....

Address: ....

....

....

Phone: ....

Name of the responsible investigator for the study:

Intan Suhana Munira Mat Azmi

Please answer the following questions. If you have any doubts or difficulty with the questions, please ask the investigator for guidance. These questions are to determine whether the proposed exercise is appropriate for you. Your answers will be kept strictly confidential.

1.	You are.......	Male	Female
2.	What is your exact date of birth? Day........... Month...........Year..19........ So your age is........................... Years		
3.	When did you last see your doctor? In the: Last week............ Last month.......... Last six months............ Year................. More than a year...........		
4.	Are you currently taking any medication?	YES	NO
5.	Has your doctor ever advised you not to take vigorous exercise?	YES	NO
6.	Has your doctor ever said you have "heart trouble"?	YES	NO
7.	Has your doctor ever said you have high blood pressure?	YES	NO
8.	Have you ever taken medication for blood pressure or your heart?	YES	NO
9.	Do you feel pain in your chest when you undertake physical	YES	NO

	activity?		
10.	In the last month have you had pains in your chest when not doing any physical activity?	YES	NO
11.	Has your doctor (or anyone else) said that you have a raised blood cholesterol?	YES	NO
12.	Have you had a cold or feverish illness in the last month?	YES	NO
13.	Do you ever lose balance because of dizziness, or do you ever lose consciousness?	YES	NO
14.	a) Do you suffer from back pain b) if so, does it ever prevent you from exercising?	YES YES	NO NO
15.	Do you suffer from asthma?	YES	NO
16.	Do you have any joint or bone problems which may be made worse by exercise?	YES	NO
17.	Has your doctor ever said you have diabetes?	YES	NO
18.	Have you ever had viral hepatitis?	YES	NO
19.	Do you have any muscle strains or aches?	YES	NO
20.	Do you know of any reason, not mentioned above, why you should not exercise?	YES	NO
21.	Are you accustomed to vigorous exercise (an hour or so a week)?	YES	NO

I have completed the questionnaire to the best of my knowledge and any questions I had have been answered to my full satisfaction.

Signed: ....

Date: ....

Appendix 4

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***

SHORT LAST 7 DAYS SELF-ADMINISTERED version of the IPAQ. Revised August 2002.

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.

SHORT LAST 7 DAYS SELF-ADMINISTERED version of the IPAQ. Revised August 2002.

Appendix 5

Stair Climbing Activity Log Sheet

Name: ________________________ Week: ______________

Date \ Time	Number of floors completed on that reminder								To be completed by researcher	
	1st	2nd	3rd	4th	5th	6th	7th	8th	Number of floors completed	Number of steps per day
Monday, …………										
Tuesday, …………										
Wednesday, …………										
Thursday, …………										
Friday, …………										

Please write in the box for each column (numbered from 1st to 8th), the number of floors you have climbed after you received the reminder. For example, if you climbed two floors on Monday when you received the first reminder, write a two in the box under column 1st.

Log sheet will be collected every Friday. We will also enter the number of steps for each day from the pedometer on this visit.

Weekend Steps: Saturday _________________ & Sunday _________________ (to be completed by researcher)

Should you have any inquiry, please do not hesitate to contact me, Intan Suhana at 07958270910 or email me at imm339@bham.ac.uk.

Appendix 6

ID:..................   Date:..

Please circle the number that best describes your response to each question.

Going to climbing the stairs when I receive the prompt on the screen is something:

I do automatically	Strongly agree	1	2	3	4	5	6	7	Strongly disagree
I do without having to consciously remember	Strongly agree	1	2	3	4	5	6	7	Strongly disagree
I do without thinking	Strongly agree	1	2	3	4	5	6	7	Strongly disagree
I start doing before I realize I'm doing it	Strongly agree	1	2	3	4	5	6	7	Strongly disagree

Thank you for completing the questionnaire