THE EFFECT OF UNIVERSITY AND THE IMPACT OF DIFFERENT MODES OF EXERCISE TRAINING ON PHYSICAL ACTIVITY AND SEDENTARY BEHAVIOUR IN THE ADULT POPULATION.

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Abstract

Physical activity (PA) is a fundamental component of a healthy lifestyle with relationships between PA and health, specifically risk factors of chronic diseases, well documented. Being highly active throughout the lifespan is vital to achieve and maintain optimal health. There are a number of different factors that can influence PA and its association with health and wellbeing in adulthood. The transition from adolescence into adulthood has been highlighted as an 'at risk' period whereby declines in the level of PA are apparent among this population. The relationship between different modalities of training and health, specifically cardiovascular function, may also impact or be related to PA, but is less well studied. Therefore, the aim of this present thesis is to explore the impact of PA and sedentary behaviour (SB) levels in university students and adult gym-users and the associations of a) university and b) different training modalities on markers of health including; body mass index (BMI), waist circumference (WC), wellbeing and vascular function.

In study 1, 39 young university students (data presented as mean ± SD), males N=20, aged 20±1 yrs and females N=19, aged 19±1 yrs, wore an accelerometer (Actigraph GT39X) for 24 hours/day over 7 consecutive days. The Warwick-Edinburgh Mental Wellbeing Scale (WEMWBS) was used to measure wellbeing. BMI and waist circumference were calculated from the participants' height and weight. The activity data collected were then analysed using an R software package, GGIR. For males, mean ± SD BMI = 24.1 ± 2.2 kg/m^2, waist circumference = 80 ± 6 cm and wellbeing = 51 ± 6 (WEMWBS). For females, mean BMI = 22.1 ± 1.7 kg/m^2, waist circumference = 69 ± 6 cm and wellbeing = 49 ± 6 (WEMWBS). Isotemporal substitution was used to establish any associations between the participants PA, SB, BMI, waist circumference and wellbeing. There were no associations between PA and BMI ($P > 0.05$), waist circumference ($P > 0.05$) or wellbeing ($P > 0.05$). On average the participants spent 12 hours per day (males = 704.09±71.51 min/day and females = 713.09±74.85 min/day) sedentary, however 100% of participants met the recommended guidelines of 150 minutes of moderate intensity PA per week (males = 126.53 ± 45.33 min/day and females = 113.26 ± 44.36 min/day). There were no associations between the reallocation of PA components and BMI, waist circumference and well-being.

In study 2, 16 adult gym-users either endurance (N = 8 aged 43±6 yr) or resistance (N = 8 aged 34±3 yr) trained wore an accelerometer (Actigraph GT39X) for 24 hours over 7 consecutive

days. BMI and waist circumference were calculated from the participants height and weight. For endurance trained participants, mean ±SD BMI = 27.4 ± 6.0 kg/m^2 and waist circumference = 88 ± 15 cm. For resistance trained participants, mean BMI = 27.6 ± 6.8 kg/m^2 and waist circumference = 81 ± 13 cm. The activity data collected were then analysed using an R software package, GGIR. A MANCOVA was used to compare PA and SB data across the two studies (university students (n=39) and adult gym-users (n = 16). When age was removed as a covariate, the adult gym-users displayed significantly higher VPA (P = 0.010) in comparison to the university students. There were no significant differences between university students and adult gym-users PA components including; SB, moderate-intensity PA (MPA) and moderate-to-vigorous intensity PA (MVPA) when gender, BMI and wear time were controlled for.

In study 2, a subgroup of the adult gym-user participants (N=8) also had their vascular function examined (using ultrasound derived flow-mediated dilatation (FMD)) using Terason T3000 and a MANCOVA was used to determine any differences in BMI, waist circumference, FMD, SB and MVPA between endurance and resistance trained individuals. There were no relationships between PA with BMI using a MANCOVA (P = 0.956), waist-circumference (P = 0.230) or markers of vascular function (P = 0.885) in either training group. Vigorous PA was significantly higher in endurance trained participants in comparison to resistance trained participants (13.77 $\pm$ 5.77 VPA and 5.47 $\pm$ 3.93 VPA, P = 0.005) when PA data was compared. All participants in both the endurance and resistance trained groups met the recommended MVPA guidelines (endurance group = 120.79 ± 34.25 min/day and resistance group = 122.88 ± 41.43 min/day.

In conclusion, no associations were evident between PA and BMI, waist circumference and wellbeing in university students. Adult gym-users displayed significantly higher VPA in comparison to the university students. There were also no relationships observed between PA, BMI, waist circumference and markers of vascular function in either endurance or resistance trained adults. The percentage of university students and adult gym-users involved in this research meeting the recommended MVPA guidelines was high. Further work is required to determine the effect of transitioning into university and undertaking different modes of exercise training on PA, SB as well as BMI, waist circumference and wellbeing in a larger number and wider-range of participants.

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Declaration

I declare that the work in this thesis is entirely my own.

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Chapter 1:

Introduction

Introduction

Physical activity and Sedentary Behaviour

Physical activity (PA) is defined as any bodily movement produced by contraction of skeletal muscle that substantially increases energy expenditure (Howley, 2001). Insufficient PA is the fourth leading risk factor for global mortality and development of major non-communicable diseases such as coronary heart disease, type 2 diabetes and breast and colon cancers (Lee et al., 2012). The risk of death is heightened by as much as 20-30% with inactivity (World Health Organisation, 2017), causing 5.3 million deaths worldwide in 2008 (Lee et al., 2012). Inactivity not only results in adverse health conditions but also places a significant burden of cost on the National Health Service (NHS), which is estimated at £1.6 billion per year. This figure is the result of numerous conditions including coronary heart disease, stroke, diabetes, and colon and breast cancer, all of which have been directly linked to physical inactivity (Allender et al., 2007). As a whole, health incorporates physical, social and mental domains but there is insufficient evidence about the levels or types of PA associated with psychological health (Eime et al., 2013). There is growing evidence around the role of sedentary behaviour (SB) as a risk factor (independent to PA), resulting in increased risks of numerous chronic conditions and early mortality in men and women (Ekelund et al., 2016). SB is any waking behaviour characterised by an energy expenditure of ≤1.5 metabolic equivalents (METS) while in a sitting, reclining or lying posture (Sedentary Behaviour Research Network., 2012). Interestingly, high levels of PA (60-75 minutes of moderate PA (MPA) per day) attenuate but do not eliminate the increased health risks associated with large amounts of sitting time (Ekelund et al., 2016). Objective measures demonstrate that the average adult spends 50-60% of their day engaging in sedentary behaviours (Healy et al., 2011), with a worldwide cost the health services an estimated $150 billion in 2013 (Ding et al., 2016).

Lifestyle changes during adulthood and University

Inactivity rises with age (Hallal et al., 2012), with a third of adults not meeting the PA guidelines (Ekelund et al., 2012) of 150 minutes of moderate-vigorous PA (MVPA) per week (Troiano et al., 2008). Most research has focused on increasing PA participation, with little work aimed at factors to prevent PA decline (Kwan et al., 2012). Major life transitions, such as starting university, are periods where individuals encounter numerous changes in many aspects of their lives which can contribute to significant alterations in behaviour (Bray & Kwan, 2006). The transition from high school to college or university is a period when students may change their PA levels and adopt unhealthy behaviours (Crombie et al., 2009). Therefore, abandonment of healthy behaviours may occur as students adapt to their new lifestyle (Deforche et al., 2015). Unhealthy behaviours include decreased PA, poor dietary quality, increased alcohol consumption, smoking and decreased sleep duration which may be related to poor wellbeing (Keating et al., 2005; Owen et al., 2010; Pengpid & Peltzer, 2014). An increase in BMI and waist circumference has been demonstrated during the first three months of university (Finlayson et al., 2012), possibly related to excessive participation in sedentary activities (Owen et al., 2010) as university students spend eight hours per day in a mix of sedentary activities (Rouse & Biddle, 2010). Peterson et al. (2018) objectively measured PA and SB of eighteen to twenty-year old university students and discovered, in contrast to the general adult population, high levels of MVPA. However, causality between university and PA patterns has not been fully established and while university may not reduce or increase PA, high levels of SB are apparent during university. Aside to PA, interventions to target SB during this transitional phase may help to alleviate the adoption of an unhealthy lifestyle. Therefore, a greater understanding of PA in young adults as they transition into adulthood is needed, to establish the underlying causes as to why this population display high levels of SB with the ultimate aim of providing interventions and influencing governmental guidelines to help reduce SB.

Guidelines and Exercise Training Modes

There are national and international guidelines around physical activity and healthy lifestyle. The Department of Health (Department of Health, 2011) published a UK-wide document titled, “Start Active, Stay Active”. The document presents guidelines on the volume, duration, frequency and type of PA required across the lifespan to achieve optimal health and well-being. There are numerous ways to increase PA including work-based activities and commuting. However, one common way is through structured exercise. Interestingly, the Department of health guidelines provide recommendations for strength training (consisting of weight-based exercises programmed by sets and reps) alongside continuous aerobic activity (consisting of dynamic activities) (Howley, 2001). The dose of PA requires much consideration as the physiological adaptations to PA vary dependent upon the dose and type

(Green et al., 2011a). Green et al. (2011b) highlighted the physiological adaptations to exercise depend upon the intensity of exercise as well as its modality, duration and frequency. Specifically, endurance and resistance exercise bring about different physiological responses both systemically and within the locally active tissues (Naylor, 2008). Endurance exercise will likely result in sustained increases in blood flow whereas resistance exercise results in episodic short-lived increases in blood pressure and potential blood flow limitation in active tissues due to muscular contraction. There is some evidence that these may result in different vascular adaptations with endurance exercise resulting in arterial wall restructuring and resistance exercise impacting on arterial compliance Green et al. (2011b). Given that these two modes of exercise produce different physiological stimuli and due to the style of training, either modality may result in differing amount of PA, further information comparing individuals who undertake specific modes of exercise training is needed. It is unknown if participating in specific modes of exercise training can have a strong impact on PA behaviour. Given the growing prevalence of individuals undertaking strength-based training (Dawson, 2015), sometimes in the absence of any endurance training, further information is needed on this relationship. Providing detailed information on the different modes of exercise and their impact on habitual PA may be useful for future recommendations and guidelines.

Physical Activity Measurement

It is worth noting that associations between PA and SB with health can be equivocal; this may be due to inconsistent findings relating to differing levels of PA intensity and to the varying methodologies used in accelerometry research (Aggio et al., 2015). University students' PA and SB have been measured subjectively and inconsistently using self-reported methods making it difficult to draw associations across samples of this population (Keating et al., 2005). This is due to difficulty accessing this specific population as a result of a busy timetable of lectures, exams and studying (Arias-Palencia et al., 2015). Therefore, there is a need to standardise PA measurement methods to better understand university students' PA (Keating et al., 2005) and help inform potential interventions and guidelines. Although literature is sparse in terms of PA measurement and trained populations, PA has been assessed using both objective and subjective methods across a variety of populations (Kapteyn et al., 2018; Troiano et al., 2008). Objective assessments such as accelerometers, provide accurate, valid and reliable PA data and capture movement in 'real time' which allows for PA assessment across the whole day (Dollman et al., 2009). Subjective measures of PA such as self-report can provide issues with PA assessment and individuals may not be able to recall information regarding their PA or training regimes. They may also misinterpret the questions and struggle to understand them. Individuals could also provide answers that they deem socially desirable (Kapteyn et al., 2018). Further work is required to examine habitual PA in individuals undertaking different exercise training modalities using objective PA assessment methods.

Isotemporal Substitution

Recent research has started to explain the effects of time reallocation of activity intensities on health in adults (Hamer et al., 2014). The isotemporal substitution model, estimates the effect of replacing SB or one PA intensity with another (e.g. replacing SB with MVPA) and the impact this has on different outcomes such as BMI and waist circumference (Hamer et al., 2014; Mekary et al., 2009). Replacing sedentary behaviour with an equivalent amount of MVPA has been associated with more favourable health and fitness outcomes in young people (Aggio et al., 2015) however, less is known in adults. These displaced activities can be heterogeneous and generate different health effects and, because available hours for voluntary activities are limited, determining the relative effects of time spent in different activities becomes of great importance to public health recommendations (Mekary et al., 2009). In older adults (60+) it has been discovered that an accumulation of MVPA in bouts shorter in duration than the recommended 10-minute minimum can still improve cardiovascular parameters (Ryan et al., 2018). These authors also established that with increased standing and engagement in light-intensity PA (LPA), older adults would achieve health benefits without engagement in MVPA. Identifying the health benefits achieved when engaging in a specific PA intensity would help to update the current PA guidelines to increase specific PA intensities to achieve optimal health. As well as help to improve knowledge and understanding of the relative importance of each PA and SB component. Therefore, accurate measurements of PA and SB are vital to establish a dose-response relationship between PA, SB and morbidity and mortality.

Aims and objectives

In order to inform future health, work is needed to examine PA levels so that interventions can be developed and relevant policies can be put in place to ensure that PA levels remain high throughout adulthood. Therefore, the **objective**s of this thesis are to 1) investigate PA and sedentary behaviour patterns during adulthood and 2) different factors that may influence PA and sedentary behaviour in adults of different ages. More specifically, two distinct groups with different lifestyle influencers will be examined a) after the transition from high school to university and b) healthy adult gym-users.

The objectives for study one were to 1) examine PA and SB levels in university students 2) investigate the effect of reallocating PA and SB time on markers of health including; body mass index (BMI), waist circumference and wellbeing.

The objectives for study two were to 1) investigate PA components including; SB, MPA, VPA and MVPA between university students and healthy (non-university) adults and 2) investigate the impact of different types of training, endurance and resistance training, on vascular function.

The overarching aim of this thesis is to investigate PA and SB behaviour patterns during adulthood in two unique populations, university students and adult gym-users. This will consist of the examination of psychological wellbeing and PA during university life and the role of different exercise training and regular gym on vascular function alongside PA and SB patterns.

Chapter 2:

Literature Review

Literature Review

Physical activity

PA is defined as any bodily movement produced by contraction of skeletal muscle that substantially increases energy expenditure (Howley, 2001). PA comprises of occupational activity, leisure activity, playing sports and exercise that is structured for fitness and health purposes and household chores (Dishman et al., 2001). The current UK guidelines state that adults aged 19-64 years should aim to be active daily; throughout the course of the week activity should add up to at least 150 minutes of moderate intensity activity in bouts of 10 min or more. This can be achieved by doing 30 minutes of moderate intensity activity 5 days a week. Alternatively, 75 minutes of vigorous intensity activity spread across the week or a combination of both can help to achieve similar benefits (Department of Health, 2011). For additional health benefits, adults should increase their moderate physical activity (MPA) to 300 minutes per week, or equivalent (U.S. Department of Health & Human Services, 2008). PA that improves muscle strength should also be undertaken at least twice a week and the amount of time adults spend sitting for extended periods should be minimised (Department of Health, 2011). A large proportion of adolescents (~80%), are undertaking less than 60 minutes per day of MVPA (Hallal et al., 2012) and as previously stated, a third of the adult population do not meet the guidelines above (Ekelund et al., 2012), demonstrating that the absence of PA is endemic.

Sedentary behaviour

SB describes any waking behaviour characterised by an energy expenditure of ≤1.5 metabolic equivalents (METS) while in a sitting, reclining or lying posture (Sedentary Behaviour Research Network., 2012). The term "sedentary" is not always used correctly or consistently, which can cause confusion among researchers, policy makers and the general public. Within the discipline, 'sedentary' is the term frequently used to describe individuals who engage in a large amount of SB, Sedentary Behaviour Research Network. (2012) therefore suggest that researchers use the term "inactive" to describe individuals who do not meet the PA guidelines to avoid confusion. Numerous adults spend in excess of seven hours per day sedentary and this typically increases with age (Matthews et al., 2008). Given the increasing availability of computers, TVs, and other technological devices, the trend of spending time engaged in sedentary behaviours involving prolonged sitting is likely to continue (Proper et al., 2011). Although individuals can be active (for example, engaging in 30 min of PA per day) they can still be classed as sedentary (sedentary for the remaining 23.5 hours in day), and may therefore still be at increased risk for many adverse health conditions including major non-communicable diseases (Ford & Caspersen, 2012; Lee et al., 2012). More specifically, there is an emerging body of evidence to indicate that SB may be an independent risk factor for multiple health outcomes, including mortality (Thorp et al., 2011). Earlier studies involved cross-sectional analyses of SB and health outcomes which provided uncertainty between the causal relationship between SB and the onset of the adverse health outcomes (Foster et al., 2006; Matthews et al., 2008). Therefore, further work is needed to examine the relationship between SB and markers of health and wellbeing in adults. More specifically, this could be examined in unique populations where high levels of SB are prevalent, such as university students (Peterson et al., 2018).

PA and SB on health outcomes

The role of PA on health outcomes has been known for a long time (Asztalos et al., 2010; Lee et al., 2012; Morris et al., 1953). Regular participation in PA aids in the prevention of risk factors for non-communicable disease and promotes cardiorespiratory fitness and muscular strength (Aggio et al., 2015). Increasing levels of PA are likely to reduce a number of adverse health parameters including cardiovascular risk factors, disease, anxiety level and increase quality of life (Lee et al., 2012). Physical inactivity is responsible for 6% coronary heart disease (CHD), 7% of type 2 diabetes, 10% of breast cancer and 10% of colon cancer and is responsible for 9% of premature mortality. If physical inactivity was to be eliminated, these conditions would reduce and/or diminish and the life expectancy of the world's population would increase (Lee et al., 2012).

Equally, growing evidence, specifically from longitudinal studies, has now demonstrated relationships between SB and all-cause mortality, Type 2 Diabetes, cardiometabolic risk biomarkers and some forms of cancer in adults (Carson et al., 2014; Sedentary Behaviour and Obesity Expert Working Group, 2010; Thorp et al., 2011) (Lee et al., 2012; Wilmot et al., 2012). Adverse health consequences of SB are not limited to older age, indeed SB is also associated with lower quality of life in adolescents, screen-based media use was directly associated with quality of life and chronic disease conditions (Lacy et al., 2012). A gradient effect exists whereby the risks for morbidity and mortality are higher for those engaging in greater volumes of SB with these risks being independent of regular moderate-to-vigorous PA (MVPA) (Thorp et al., 2011). Ekelund et al., (2016) stated that high levels of MVPA reduce but do not eliminate the increased risk of death associated with high television viewing time. Therefore, it is essential that SB is reduced, across the life course where possible.

There may be a number of different mechanisms, which underpin improved health and wellbeing with PA. Cardiovascular disease is the leading cause of death world-wide (Yusuf et al. 2015), and the process which underlies many cardiovascular diseases is atherosclerosis. Atherosclerosis is a process by which the arteries stiffen and begin to develop plaques (Ross, 1999) and the early stages of this disease are characterised by poor vascular function (Green et al., 2011b). However, there is abundant evidence to suggest that being physically active, specifically performing exercise training, improves vascular function, thereby reducing the atherosclerotic process (Green et al., 2004) which underlies CVD. This may be related to changes in traditional risk factors such as blood pressure and lipid profiles (Green et al., 2011b). However, it may also relate to improvements in the health of the blood vessels. Increased blood flow, brought about by PA, increases shear stress that stimulates the endothelium (the inner layer of blood vessels) to produce nitric oxide (NO). Consequently, short-term exercise increases NO bioactivity thereby improving endothelial function and reducing numerous processes underlying atherosclerotic progression (including improved relaxation of the blood vessel, inhibition of leukocyte chemotaxis and platelet adhesion (Napoli et al., 2006). Taken together the PA induced improvement in NO and associated reduction in the atherosclerotic process reduces the occurrence of CVD (Green et al., 2004). In addition to vascular health, regular and adequate levels of PA improve cardiorespiratory and muscular fitness and improve bone and functional health, which reduces the risk of falls that may result in hip fractures and further SB in older adults (Lee et al., 2012; World Health Organisation, 2017). Increased PA and decreased SB are also associated with improved mental health including improved well-being, reductions in depression and anxiety (Eime et al., 2013). However, the exact mechanisms by which increased PA or reduced SB improves mental health are not fully understood. Nonetheless, it is thought that mechanisms may relate to enhanced self-esteem, fewer depressive symptoms and improved confidence (Eime et al., 2013). Therefore, it is evident that, irrespective of the mechanisms underpinning physiological or psychological improvements, they both demonstrate unique beneficial relationships with PA components.

The influence of transitioning from adolescence to early adulthood on PA

Many of the measured markers of health, such as cardiovascular disease, Type 2 Diabetes and Cancer, are more prevalent with aging. There are numerous lifestyle factors that may underlie this, specifically transitional periods (McNaughton et al., 2012). Where PA decreases and SB increases across the lifespan (Hallal et al., 2012). There is a lot of focus on research in children and older adults, however less attention has been given to the transition between childhood/adolescence to adulthood, including those of university age, where large increases in SB and decreases in PA are reported (Peterson et al., 2018). PA levels and habits are modifiable and the benefits achieved are greater the earlier they occur for changes in behaviours (Arias-Palencia et al., 2015). Equally, there are many factors with adults that can impact on PA behaviour including work, community and leisure time, transport and activities (Bauman et al., 2012). Some of these are modifiable, particularly leisure time pursuits, and represent a behaviour that can be targeted to improve PA. Therefore, more work is needed to look at factors that can influence PA and associated markers of health in the adult population.

PA and the influence of aging and transitional periods on mental health

In addition to the role of PA on physical health, mental health is also associated with the ageing process as it is a period of social and psychological transition (McNaughton et al., 2012). Specifically, the transition to university has been demonstrated as a time of heightened psychological distress (Bewick et al., 2010). Tyson et al. (2010) stated that sixty-percent of students showed elevated levels of anxiety as a result of multiple stressors including; academic work, employment, finances, accommodation and relationships. They concluded that PA promotion could safeguard students' emotional wellbeing and help to maintain and promote their mental health. In an older adult population participation in PA has been highlighted as beneficial for cognitive health (Pasco et al., 2011). Improvements in mental wellbeing in young people have been demonstrated as the result of PA (Whitelaw et al., 2010). These authors categorised mental wellbeing into three dimensions; emotional, social and psychological. Asztalos et al. (2010) highlighted in the general adult population that the PA-mental health relationship is positive across the entire PA intensity spectrum. They stated that all PA intensities were positively associated with emotional wellbeing or inversely associated with psychological complaints demonstrated by feelings of depression, anxiety and symptoms of somatisation. They demonstrated positive associations between VPA and mental health in men and positive associations between MPA and mental health in women. Although all PA intensities improve mental health, it is evident from the literature that the results attained can be gender-specific. Conclusively, throughout adulthood symptoms of poor mental health are apparent, specifically during periods of transition, but these symptoms can be reduced through the promotion of PA. Therefore, further information around levels of PA and associations with well-being in periods of heightened psychological distress are needed to assess mental health.

Definitions of training modalities; potential impact endurance and resistance exercise on PA, differing physiological and vascular responses

Structured exercise is one way to increase PA and improve health (Swift et al., 2014). Traditionally, aerobic exercise was targeted as a key mode to improve PA. However, there is growing participation in strength-based exercise. Aerobic training involves large muscle groups that results in substantial increases in heart rate and energy expenditure (Howley, 2001). Resistance training is specifically designed to increase muscular strength, power and endurance by varying the resistance, the repetitions performed, the number of sets completed and the rest period between sets (Howley, 2001).

The majority of data in the literature investigating resistance training is more focussed on physiological adaptations (Maiorana et al., 2001) as opposed to its relationship with PA and SB. Currently there is a lack of research examining different modes of exercise, and associations with PA, SB and health. Therefore, further work is therefore needed to determine if these two modes of training can influence PA and what impact this may have on markers of cardiovascular health. However, whilst the relationships are uncertain, it is well known that exercise training results in numerous benefits. Improvements in the function of the cardiovascular system and skeletal muscles are seen with regular participation in this type of activity (Green et al., 2011b; Naylor, 2008). Greater increases in blood vessel vasodilatory capacity have been demonstrated by resistance training in comparison to aerobic training (endurance training) (Collier et al., 2008). However, Aggio et al. (2015) demonstrated that MVPA was associated with favourable effects on body fat percentage, flexibility and leg power. Conversely, no associations between PA with handgrip strength and peak expiratory flow have been reported. Nonetheless, the data typically highlight the importance of promoting muscle strengthening activities as well as attaining the MVPA guidelines (Aggio et al., 2015). As well as producing distinct muscular adaptations, distinct exercise training modes may induce unique individual vascular adaptations (Green et al., 2005). The underlying mechanism for these findings are thought to be differences in brachial artery blood flow and shear rate patterns and blood pressure (Thijssen et al., 2009a). Equally, increased SB can also impact on vascular function; resulting in increased vasoconstrictor tone and smaller vessels, although the role on vascular function is less clear (Hopkins et al., 2012;Thijssen et al., 2010). Therefore, further work is needed to determine the interaction between PA and SB different exercise modes and distinct physiological adaptations.

Physical Activity and Sedentary Behaviour Measurement

The relationship between PA, SB and health outcomes is complex, therefore it requires valid and reliable quantification (Celis-Morales et al., 2012; Dishman et al., 2001). Important components of PA measurement includes: frequency, intensity, time, duration, and domain (Kesaniemi et al., 2001). Typically self-reported questionnaires have been utilised to assess PA and SB, simply because they are easy to administer, cost effective and do not disrupt daily living behaviour (Kapteyn et al., 2018). However, self-report methods used to assess PA pose issues, as they require individuals to read, process and answer questions that they perhaps struggle to understand. Certain self-report instruments are interpreted differently by individuals from different societies, cultures and countries which causes variation in responses when reporting their PA (Kapteyn et al., 2018). As a result of this, accelerometry has become the most commonly used objective method to measure PA and SB (Hildebrand et al., 2017).

Accelerometers come in the form of a wearable device, most commonly as a watch worn on the wrist (Vanhees et al., 2012). Accelerometers are motion sensors that detect accelerations produced by the human body (Welk, 2002). These accelerations are related to a measure of energy expenditure (Hildebrand et al., 2014) or PA behaviour (Mackintosh et al., 2012). There are piezoelectric transmitters located inside accelerometers that are stressed by accelerative forces, which yield an electrical signal and this provides an indication of movement (Chen & Basset, 2005; Welk, 2002). Traditionally, accelerometers were worn on the hip as it was thought that this site provided the most accurate estimations of energy expenditure and activity intensity as it was closer to the centre of mass (Rosenberger et al., 2013). However, waist-mounted accelerometers miss some PA that involves upper body movement or the additional energy cost of load carrying (Troiano et al., 2008). Wrist-worn accelerometers promote better compliance (Troiano et al., 2008; Vanhees et al., 2012) and allow for the examination of low-intensity PA during household work and even sleep (Ekblom et al., 2012). They can also detect non-ambulatory movements such as cycling and reduce the burden of wear (Ridgers & Fairclough, 2011).

Rapid developments in accelerometry have been seen over this last decade (Rowlands et al., 2016) as monitors now have the capacity to measure at high frequency over twenty-four hours, for seven days to facilitate accurate measurement of the full spectrum of physical behaviours including; PA, SB and sleep (Buman et al., 2014). SB to date has most commonly been assessed using self-reported questionnaires or objective measures including wrist or waist worn accelerometers (Edwardson et al., 2017).

Raw analysis of accelerometry

Historically, the acceleration signals collected by accelerometers were reduced into proprietary units called counts using manufacturer software. This data was stored in 5-60 second epochs and time spent in MVPA was provided (Rowlands et al., 2016). As a result of how raw data are processed, filtered and scaled (Fairclough et al., 2016), it made it difficult for researchers to compare data between different monitor brands (Hildebrand et al., 2014). The latest versions of accelerometers provide raw, unfiltered acceleration signals, which are captured at high frequencies. These signals are then reduced into metrics using open source processing. Therefore, comparisons between studies using various brands can be made more easily due to the nature of control that raw acceleration data offers (Hildebrand et al., 2014).

GGIR (Raw Accelerometer Data Analysis) is an R package that provides various tools to process raw accelerometer data from GENEActiv and Actigraph GT39X devices, these provide raw acceleration data expressed in gravity (g) units (van Hees et al., 2014). The signal processing includes automatic calibration, detection of sustained abnormally high values, detection of non-wear, imputation and calculation of the average magnitude of dynamic acceleration (ENMO). After processing, the outputs provided by GGIR are in the format of Excel spreadsheets, which consist of a variety of outcome variables describing the activity profile, MVPA and sleep of individuals who have worn the devices. Taken together, improvements in equipment, data acquisition, and analysis have resulted in reduced bias and improves precision and enhanced measurement opportunities for researchers (Troiano et al., 2014). Therefore, future work utilising objective measures of PA, specifically analysing raw data, would be beneficial to draw meaningful comparisons of PA components between studies.

Isotemporal substitution

The health benefits of different PA activities depend not only on the specific activity but also on the activity it displaces (Mekary et al., 2009). Adolescents who display high MVPA have been associated with better cardiometabolic risk factors regardless of the amount of time they spend being sedentary (Ekelund et al., 2012). Carson et al. (2013) highlighted that time spent in low light-intensity PA and light high-intensity PA had some favourable associations with cardiometabolic biomarkers such as blood pressure. It is still unclear as to how the reallocation of time from one activity intensity to another affects health (Aggio et al., 2015) and which PA intensity actually elicits the most beneficial effects on health however, using isotemporal substitution, it has been suggested that MVPA may be the most compelling health-enhancing behaviour (Buman et al., 2014). Isotemporal substitution simultaneously models the effect of displacing one activity for the same amount of time spent in another activity (Aggio et al., 2015; Hamer et al., 2014). Displaced activities can be heterogeneous and diversely effect health, determining the effects of time spent in different activities therefore becomes of great importance to the public health recommendations (Mekary et al., 2009). The isotemporal substitution technique consists of three models, single factor, partition and isotemporal substitution models to analyse the effect of substituting one intensity category for another whilst controlling for total wear time (Hamer et al., 2014). This technique now explains the effect of reallocation of activity intensities on health parameters in adults (Hamer et al., 2014). Isotemporal substitution has be shown to demonstrate the positive effects on health when certain activities have been displaced with another. For example, a reduced CVD risk profile can be shown when substituting SB with time spent in both MVPA and LPA (Buman et al., 2014). Future work should investigate these components of PA throughout the lifespan, and with different types and intensities of exercise to draw meaningful conclusions about the variety of intensities and modes of exercise and PA with health.

Objectives

The overarching aim of this thesis is to investigate PA and SB behaviour patterns during adulthood in two unique populations, university students and adult gym-users. This will consist of the examination of psychological wellbeing and PA during university life and the role of different exercise training and regular gym on vascular function alongside PA and SB patterns.

The objectives of this thesis are to 1) investigate PA and sedentary behaviour patterns during adulthood, specifically after the transition from high school to university 2) investigate the impact of different types of training, endurance and resistance training, on vascular function 3) investigate PA components including; SB, MPA, VPA and MVPA between university students and healthy adult gym-users.

Chapter 3:

Associations between Physical Activity and Sedentary Behaviour with BMI, Waist Circumference and Wellbeing in Undergraduate University Students.

Associations between Physical Activity and Sedentary Behaviour with BMI, Waist Circumference and Wellbeing in Undergraduate University Students.

Regular physical activity (PA) reduces non-communicable diseases such as coronary heart disease, type 2 diabetes and breast and colon cancers as well as all-cause mortality (Aggio et al., 2015; Kesaniemi et al., 2001; Lee et al., 2012; Wilmot et al., 2012). This may be, in part, related to a reduction in metabolic syndrome including overweight and obesity that is often associated with low PA and non-communicable disease incidence (Lee et al., 2012). Aside to physiological health, mental illness has been recognised as a serious public health issue (Biddle & Asare, 2011) and is expected to account for 15% of the global burden of disease by 2020 (Biddle & Mutrie, 2008). However, the association between PA and reduced mental illness has been less studied (Sanchez-Villegas et al., 2008). Previous studies have explored this issue in clinically defined populations as opposed to populations who display the absence of any overall mental health problems (Tyson et al., 2010).

There is a lack of evidence to support just how much PA is required to alleviate mental health disorders and it is suggested that the amount of PA is a stronger determinant as a therapeutic effect on mental diseases (Dunn et al., 2005). In a sample of university students, participants with higher levels of PA per week had a reduced risk of mental health disorders compared to those less active individuals (Sanchez-Villegas et al., 2008). A positive dose-response relationship has been demonstrated between increased PA and improved mental health, whereby the greater the PA the lesser the symptoms of anxiety and depression in a cohort of undergraduate university students in Gloucestershire (Tyson et al., 2010). Participants were allocated into low, medium and high PA groups. The mean PA score for the low group was 3.26 minutes, 68.45 minutes for the medium group and 554.94 for the high PA group. Using subjective measures, the high PA group demonstrated the significantly lowest ratings of anxiety and lowest levels of depression. Understanding the behavioural changes that take place during this period is critical to ensure optimal adult health is achieved (Rouse & Biddle, 2010), especially since PA during this formative stage is critical for laying a foundation for the adult life patterns (Irwin, 2004). PA habits and patterns displayed by university students are modifiable, and the benefits achieved are greater the earlier they occur for changes in behaviour (Arias-Palencia et al., 2015).

Isotemporal substitution has demonstrated positive effects on health when certain activities are displaced with another including: improvements in glucose, insulin and insulin sensitivity when sitting was substituted for standing or stepping (Edwardson et al., 2017), improvements in body fat, flexibility and leg power when sedentary or light activity was replaced with MVPA (Aggio et al., 2015) and a reduced CVD risk profile when greater time is spent in both MVPA and LPA (Buman et al., 2014). However, when SB has been reallocated for MVPA unfavourable effects on health have been demonstrated (Aggio et al., 2015). Currently, there is little information regarding the reallocation of SB and PA in university students on markers of health and wellbeing.

The objectives of this study were:

1) To examine PA and SB levels in university students.
2) To investigate the effect of reallocating SB and PA time on markers of health including BMI and waist circumference and wellbeing in university students.

Hypothesis:

The reallocation of time from sedentary activity to LPA and MVPA will be favourably associated with BMI, waist circumference and wellbeing.

<u>Methods:</u>

Study design: This was a retrospective study employing secondary data analysis of a previously conducted cross-sectional study.

Participants: Ethical approval was granted by the Research Ethics Committee of Liverpool John Moores University (LJMU) for a student health project. Approximately~250 undergraduate students who were scheduled to complete formal physical activity practical sessions as part of their level 4 curriculum were asked if they would like to take part in the research study. Students were provided with information sheets and participants were asked to ‘opt out’ of the study if they did not want to take part. The inclusion criteria required students to be enrolled on the LJMU Sport and Exercise BSc programme at or over the age of 18 years and to have provided informed consent. Participants were excluded if they did not provide informed consent.

Outcome measures:

Anthropometrics: Height was measured to the nearest 0.1cm using a Leicester height meter (Seca, Bodycare, Birmingham), body mass was measured to the nearest 0.1kg using calibrated scales (Seca, Bodycare, Birmingham). Waist circumference were measured to the nearest 0.5cm using a non-elastic tape passed around the narrowest point between the iliac crest and the bottom of the ribs for the waist circumference assessment.

Wellbeing assessment:

Participants completed the Warwick-Edinburgh Mental Wellbeing Scale (WEMWBS) long version (Tennant et al., 2007). They were given the 14-item scale survey to complete on their own and return to the research team during the second practical session. The total score of the survey was obtained by summing the score for each of the 14 items. These range from 1-5 and the total score from 14 to 70. If a participant had not completed all 14 statements then their survey could not be used for analysis, as it was classed as inaccurate (NHS Health Scotland, 2006). The range of scores for WEMWBS is a minimum score 14 and a maximum score of 70, higher scores indicate a higher level of mental wellbeing among individuals (Clarke et al., 2011).

Objective assessments of physical activity and sedentary behaviour:

Forty-nine students were randomly selected by being drawn out of a hat, stratified by gender and were asked to wear an ActiGraph (GT39X) accelerometer on their non-dominant wrist for 24 hours over 7 consecutive days. The monitors were initialised at a sampling frequency of 30 Hz. Participants were provided with instruction on how to wear the monitor and told to remove it during water based activity, showering/swimming and during contact sports.

Participants were asked to record when the monitor had been removed using a paper log. Once the 7-day monitoring period was over, participants were asked to hand back their ActiGraph monitors to the research team.

ActiGraph data were downloaded using ActiLife v. 6.11.4 (ActiGraph, Pensacola, FL) and saved in raw format as GT3X files. These were subsequently converted to CSV format to facilitate raw data processing. ActiGraph wrist raw data files were then processed in R (http://cran.r-project.org) using the GGIR package (version 1.2-11). GGIR is an R studio package that processes raw accelerometer data and has been designed for data collected under free-living conditions (van Hees et al., 2014). This process involved the conversion of raw triaxial acceleration values into one omnidirectional measure of acceleration, termed the signal vector magnitude (SVM). SVM was calculated from raw accelerations from the three axes minus 1g which represents the value of gravity (i.e., SVM = $\sqrt{(x^2 + y^2 + z^2)} - 1$), after which negative values were rounded to zero. This metric is referred to as the Euclidean norm minus one (EMNO) (van Hees et al., 2013). Minimum wear time was set at 10 hours per day, and participants had to provide at least three valid days of data. Non-wear time was estimated in GGIR based on the standard deviation and value range for each axis, which was calculated for 60-minute windows with 15-minute moving increments. If the standard deviation was less than 13 mg or the range was less than 50 mg for at least 2 of the 3 axes this period was classed as non-wear (Rowlands et al., 2016). In this study, the default non-wear setting was used in GGIR whereby invalid data were imputed by the average at similar time points on different days of the week (Rowlands et al., 2016).

Device specific prediction equations provided by Hildebrand et al. (2014) were used to identify ENMO cut points for classifying MVPA in milligravity units. The specific thresholds used were, 0-44m*g* (Sedentary), 45-99m*g* (LPA), 100-428m*g* (MPA), and ≥429m*g* (VPA).

Statistical analysis:

Descriptive statistics were calculated for all participant characteristics and differences between males and females were examined using Independent t-tests for each. Linear regression (Hamer et al., 2014) examined associations between sedentary activity, light activity and moderate-to-vigorous physical activity (MVPA). Three models were implemented and adjusted for sex and age. The first were single factor models to analyse the association between time in each intensity category and health outcomes without mutual adjustment for other intensity categories. This model examines each activity intensity separately without taking into account the other activity intensities. Each activity intensity was entered into this model separately with covariates, for example, sedentary time in the first version of this model followed by another four individual versions for LPA, MPA, VPA and MVPA. The second models used were partition models to analyse the association between time in each intensity category and health outcomes, with mutual adjustment for time spent in other intensity categories, but not controlling for total wear time. This model partitions total activity intensity among its components. The co-efficient for one type of activity intensity represents the effect of increasing this type of intensity while holding other intensities constant; it demonstrates the effect of adding as opposed to substituting an activity intensity. All PA intensities were entered simultaneously into the model. The third models used were isotemporal substitution models to analyse the effect of substituting one intensity category for the category dropped whilst controlling for total wear time. This model estimates the effect of replacing one PA intensity with another PA intensity for the same amount of time. By eliminating one PA intensity from the model, the co-efficient for total activity represents the omitted activity component (Mekary et al., 2009). For example, isotemporal substitution models that examined the effect of replacing sedentary time with MVPA, the model consisted of LPA, MVPA, total wear time and other covariates including sex and maturation. Whereas a model examining the effect of replacing MVPA with sedentary time included sedentary time, LPA, total wear time and other covariates including sex and maturation (Hamer et al., 2014). For all analyses, statistical significance was set at $P<0.05$. All analyses were conducted using IBM SPSS Statistics v.23 (IBM, Armonk, NY).

Results:

Participant characteristics: Forty-nine participants provided accelerometer data however only 39 of these met the inclusion criteria for analysis, 20 males and 19 females. Of the 10 participants that were not included in analysis, eight participants were removed as they did not meet the minimum wear time inclusion criteria and two participants were removed as they did not provide any anthropometric data. Participant characteristics, including anthropometric data can be viewed in Table 1. A total of eight hours were removed from each participant's daily sedentary time to account for time a sleep (Fairclough et al., 2017). All 39 participants were included for BMI analysis, 38 for waist circumference analysis as one participant did not provide a waist circumference measure and 35 were included for WEMWBS analysis, four participants were removed as they did not provide a WEMWBS score. All WEMWBS scores were either average or above average for all participants' mental wellbeing.

Participant characteristics are displayed below (table 1). Male participants were significantly older ($P = 0.017$) and displayed significantly higher values for body mass ($P \leq 0.01$), stature ($P \leq 0.01$) and BMI ($P = 0.002$). No female participants were classified as overweight or obese however, forty percent of male participants were classed as overweight with none reported as obese. All participants met the current PA guidelines of 150 minutes of moderate intensity physical activity per week.

Table 1: Participant characteristics

Measure	Males (n=20)	Females (n=19)	Independent t-test (*P* =)
Age (years)	20 ± 1	19 ± 1	0.017*
Body Mass (kg)	74 ± 7	60 ± 7	<0.001*
Stature (m)	1.75 ± 0.06	1.64 ± 0.06	<0.001*
BMI	24.1 ± 2.2	22.1 ± 1.7	0.002*
- Overweight (%)	40	0	
- Obese (%)	0	0	
Waist Circumference (cm)	80 ± 6	69 ± 6	0.122
WEMWBS	51 ± 6	49 ± 6	0.179
MVPA (% meeting 150 minutes/week)	100	100	
MVPA (minutes/day)	126.53 ± 45.33	113.26 ± 44.36	0.361
SB (minutes/day)	704.09±71.51	713.09±74.85	0.704
LPA (minutes/day)	129.38±30.23	133.65±32.60	0.674
MPA (minutes/day)	117.80±41.73	107.23±41.33	0.432
VPA (minutes/day)	8.73±5.21	6.03±4.55	0.092

Participants overweight are displayed as a percentage (%) of BMI for both genders. No participants were classed as obese. Significant P values are displayed with an asterisk (*), *P* <0.05.

Tables 2-4 present coefficients for single, partition and isotemporal substitution models. Sedentary time was excluded in the partition model due to a collinearity issue. Our findings demonstrate no positive or negative associations or significant effects for replacing one intensity (SB, LPA, MVPA) with another on our three dependent variables: BMI, waist circumference and WEMWBS.

Table 2: Single, partition and isotemporal substitution models examining the relationship between changes in time spent (hours/day) in sedentary, light and moderate-to-vigorous intensity activity and BMI (kg/m^2) (n = 39).

Models	**Sedentary, *B* (95 % CI), R square and *P* value**	**Light activity, *B* (95 % CI), R square and *P* value**	**MVPA, *B* (95 % CI), R square and *P* value**
Single	-0.001 (-0.010-0.009) 0.224 0.891	0.005 (-0.017-0.027) 0.228 0.658	-0.001 (-0.016-0.015) 0.224 0.933
Partition	*EXCLUDED*	0.018 (-0.022-0.058) 0.243 0.359	-0.011 (-0.039-0.017) 0.243 0.417
Isotemporal substitution			
Sedentary	**Dropped**	0.020 (-0.021-0.061) 0.248 0.332	-0.012 (-0.041-0.016) 0.248 0.382
LPA	-0.020 (-0.061-0.021) 0.248 0.332	**Dropped**	-0.032 (-0.099-0.034) 0.248 0.333
MVPA	0.012 (-0.016-0.041) 0.248 0.382	0.032 (-0.034-0.099) 0.248 0.333	**Dropped**

Regression coefficients (95% CI) were adjusted for sex, maturation and wear time. Those statistically significant are marked with an asterisk (*), P <0.05.

Table 3: Single, partition and isotemporal substitution models examining the relationship between changes in time spent (hours/day) in sedentary, light and moderate-to-vigorous intensity activity and Waist Circumference (cm) (n = 38).

Models	**Sedentary, *B* (95 % CI), R square and *P* value**	**Light activity, *B* (95 % CI), R square and *P* value**	**MVPA, *B* (95 % CI), R square and *P* value**
Single	0.005 (-0.027-0.037) 0.456 0.747	0.000 (-0.072-0.071) 0.454 0.994	-0.015 (-0.069-0.040) 0.459 0.588
Partition	*EXCLUDED*	0.055 (-0.078-0.188) 0.470 0.408	-0.050 (-0.152-0.052) 0.470 0.325

Isotemporal substitution			
Sedentary	**Dropped**	0.048 (-0.088-0.183) 0.480 0.477	-0.045 (-0.148-0.059) 0.480 0.385
LPA	-0.048 (-0.183-0.088) 0.480 0.477	**Dropped**	-0.093 (-0.322-0.137) 0.480 0.418
MVPA	0.045 (-0.059-0.148) 0.480 0.385	0.093 (-0.137-0.322) 0.480 0.418	**Dropped**

Regression coefficients (95 % CI) were adjusted for sex, maturation and wear time. Those statistically significant are marked with an asterisk (*), P <0.05.

Table 4: Single, partition and isotemporal substitution models examining the relationship between changes in time spent (hours/day) in sedentary, light and moderate-to-vigorous intensity activity and WEMWBS (n = 35).

Models	**Sedentary, *B* (95 % CI), R square and *P* value**	**Light activity, *B* (95 % CI), R square and *P* value**	**MVPA, *B* (95 % CI), R square and *P* value**
Single	0.010 (-0.016-0.037) 0.051 0.440	-0.035 (-0.098-0.028) 0.070 0.272	-0.011 (-0.055-0.033) 0.040 0.613
Partition	*EXCLUDED*	-0.078 (-0.202-0.045) 0.092 0.203	0.035 (-0.049-0.119) 0.092 0.403
Isotemporal substitution			
Sedentary	**Dropped**	-0.079 (-0.206-0.048) 0.092 0.215	0.035 (-0.052-0.122) 0.092 0.414
LPA	0.079 (-0.048-0.206) 0.092 0.215	**Dropped**	0.114 (-0.093-0.321) 0.092 0.269
MVPA	-0.035 (-0.122-0.052) 0.092 0.414	0.114 (-0.321-0.093) 0.092 0.269	**Dropped**

Regression coefficients (95 % CI) were adjusted for sex, maturation and wear time. Those statistically significant are marked with an asterisk (*), P <0.05.

Discussion:

This study models the association of reallocating time spent in sedentary activity, LPA and MVPA on associations with BMI, waist circumference and wellbeing (assessed using WEMWBS) in university students using isotemporal substitution. The objective of the study was to investigate the PA and SB levels in university students and establish relationships between these and markers of health.

BMI and waist circumference

All three models, single, partition and isotemporal, showed no associations between SB, LPA and MVPA on BMI or waist circumference. There are some limitations with BMI as a marker to classify weight status, as BMI does not discriminate fat from lean mass and both of these have very different health implications (Snijder et al., 2006). This provides explanation as to why BMI inaccurately identifies individuals with excess body fat between the BMI ranges of 25-29.9kg/m^2 and men (Romero-Corral et al., 2008). Excess abdominal fat accumulation can be estimated using the measurement of waist circumference. However, waist circumference should not replace BMI, rather is should be used in combination with BMI as they are strongly correlated at the population level (Cerhan et al., 2014). Individuals can have a large waistlines because they have overall obesity whereas other individuals are not classed as obese, but have a larger waistline because they have excess abdominal fat (Despres, 2011). In support of our findings, Peterson et al. (2018) discovered that university students display high levels of PA as well as high levels of SB and a lack of evidence to support a relationship between high amounts of SB and increased BMI and waist circumference.

However, in contrast to our results SB has been associated with increases in BMI at the 90th, 75th and 50th BMI percentiles between children aged nine to fifteen years old (Mitchell et al., 2013) and waist circumference (Healy et al., 2011) independent of MVPA. Carson et al. (2013) reported beneficial associations with MVPA and cardiometabolic biomarkers, specifically lower waist circumference values when MVPA was undertaken in adolescents, aged 12-19 years. Interestingly, time spent in LPA demonstrated beneficial associations with cardiometabolic biomarkers which suggests LPA may act as a beneficial accompaniment the current MVPA recommendations (Carson et al., 2013). Similarly, Ekelund et al. (2012)

demonstrated that higher MVPA time in adolescents was associated with better cardiometabolic risk factors, independent of the amount of time spent sedentary. However, neither MVPA nor SB was associated with waist circumference but higher waist circumference values at baseline were associated with higher amounts of SB at follow-up. In adults, replacing SB with MVPA was associated with favourable effects in metabolic risk factors including BMI as well as when LPA was replaced with MVPA (Hamer et al., 2014). Some research in older adults have demonstrated better physical health by replacing SB with LPA (Buman et al., 2010). This may be related to the older subjects in the Buman study who had more adverse physical health conditions comparison to this study's subjects who were young, healthy and relatively homogeneous. Higher waist circumference values have been positively associated with higher mortality at all levels of BMI from 20-50kg/m^2 in adults (Cerhan et al., 2014). These authors suggest that waist circumference should be assessed in combination with BMI as jointly they serve as important predictors of mortality in the general population.

There may be a number of different reasons for the disparity between the findings in this study and the majority of the literature. The participants in this study could have been classed as being an athletic population given their chosen degree and supported by the fact that their waist circumference values were classed as healthy. This indicates the need for better assessment tools as it is clear that body shape and how excess fat is stored, can influence BMI results. Perhaps if this study had of collected baseline data and then had a follow-up data collection period, different results may have been observed. Rouse and Biddle (2010) stated that university students spend eight hours per day in sedentary pursuits including: sitting and socialising, watching television and studying. Excessive participation in sedentary activities has been associated with an increased risk of obesity, independent of PA (Owen et al., 2010). In contrast, both males and females in this study spent an average of twelve hours sedentary per day, but were also active enough to meet current PA guidelines. Again, this highlights the aspect that they participants in this study were active individuals. Although it has been suggested that the effects of SB can be attenuated not eliminated. A study investigating MVPA and SB and cardiometabolic risk factors in participants aged four to eighteen years old highlighted that regardless of the amount of time spent sedentary, higher MVPA time was associated with better cardiometabolic risk factors including, waist circumference, systolic blood pressure, HDL cholesterol and insulin (Ekelund et al., 2012). Further high levels of MPA have been demonstrated to eliminate the increased risk of death associated with high levels of SB (Ekelund et al., 2016). A large scale study in the UK demonstrated weight gain during the first three months of this transitional period to university, evidenced by markers of adiposity including; significant increases in BMI, waist circumference and fat mass (Finlayson et al., 2012), reductions in these markers have been apparent in adults when SB has been replaced with LPA and MVPA (Aggio et al., 2015; Buman et al., 2014; Hamer et al., 2014). However, the participants in this study had been enrolled at university for five months before data collection and as mentioned above, all participants displayed healthy waist circumference values. Evidently, as these participants were highly active, helping to attenuate any effects of SB. However, currently it is still unclear as to whether PA attenuates or even eliminates the detrimental effects of prolonged sitting (Ekelund et al., 2016) and this is an area that requires further evaluation.

Wellbeing

All three models, single, partition and isotemporal, showed no associations with WEMWBS scores. In contrast to our findings Bray and Kwan (2006) examined the association of vigorous PA (VPA) with psychological wellbeing and illness during first year students' transition to university life. Although results were not significant, they discovered a general indication that students who participated in sufficient levels of VPA during this transition had more positive psychological wellbeing than those who were not sufficiently active. In this study, the average time participants spent in VPA was nine minutes for males and six minutes for females per day. Interestingly, participants with low VPA levels still demonstrated similar WEMWBS scores to that of participants with higher VPA levels, all WEMWBS scores were within a healthy range. Bewick et al. (2010) highlighted that distress levels were highest during semester one of students' first year but with significant reductions in psychological distress from semester one to semester two. This may explain our findings as the data were collected at the beginning of February in semester two, as it was part of one of their taught modules in this semester. University is often seen as an anxiety-provoking time (Bewick et al., 2010) and that the transition to university is associated with increased physical and psychological health problems. This can be due to examinations, forming new relations and being able to live independently after having had to move away from existing family and friendship relations (Bray & Kwan, 2006). Therefore, it is crucial that student's develop the ability to cope with the stressors associated with university life to help maintain both physical and mental health (Vankim & Nelson, 2013).

Replacing sedentary activity with LPA has been associated with significant benefits to wellbeing in older adults (Buman et al., 2010). There is existing evidence examining the relationship between PA and wellbeing, which suggests that increased PA is associated psychosocial factors including; moods that are more positive, enhanced self-esteem and a reduction in levels of anxiety (J. Spence et al., 2005). Findings from the study by Vankim and Nelson (2013) demonstrated that students who met PA recommendations, specifically for VPA, in university were less likely to report poor mental health as well as perceived stress in comparison to those who did not meet the recommendations. It would have been interesting to collect wellbeing data pre-transition to establish if there were any changes in wellbeing prior to the transitioning period. The students involved in this study were active and healthy individuals, which could explain our findings of no significant associations with wellbeing and PA intensity possibly because they were sport and exercise science students. Therefore, a need for creating environments where students can easily engage in PA to improve wellbeing and sustain PA levels during this transitional phase is vital.

Strengths:

This is the first study to examine the effects of reallocating time spent in specific activity intensity categories and the impact these have on BMI, waist circumference and wellbeing (WEMWBS) in university students. Our results should provide novel findings that will set scope for future research within this specific population using the isotemporal substitution model. Other strengths of the study include objectively assessed PA and the use of a validated survey to assess wellbeing in the adult population.

Limitations:

The key limitation to this study was that a biased sample population was investigated, as the participants were sport and exercise science students and were all classified as physically active. This was a cross-sectional study and the sample used consisted of a small, active, healthy, homogenous individuals, which could explain our lack of significant findings. Although the ActiGraph GT39X identifies levels of MVPA well, it is less accurate for distinguishing levels of sedentary and light activity (Kozey-Keadle et al., 2011). This may explain why our findings demonstrate limited effects of substituting sedentary time for light activity. Therefore, it may have been more useful to use devices capable of examining posture, for example the activPal, which has shown high correlations and excellent agreement with direct observation (Kozey-Keadle et al., 2011). Participants were instructed to remove accelerometers when swimming, showering or taking part in contact sports therefore, we cannot account for activities undertaken during this period. The published thresholds used were the best available however were not specifically developed for the population of interest therefore future research could calibrate a set of thresholds for this specific population. Removing 8 hours from participants' sedentary time to account for sleep may provide some inaccuracies. WEMWBS represent a method of self-report, which can cause limitations due to incomplete recall, impaired cognitive ability, and influence of socially desirable answers (Kapteyn et al., 2018). Although it is a validated measure for mental wellbeing, some individuals may have struggled to understand the questions on the scale or may have been slightly embarrassed to answer certain questions therefore misreporting their wellbeing

Conclusion:

In summary, the findings demonstrate no significant effects of reallocating SB, LPA or MVPA on BMI, waist circumference and wellbeing. Further research is essential, to aid understanding of the varied lifestyle of university students and the impact this has on students' level of PA and sedentary activity, health and wellbeing. Investigating this population across their entire degree program may be more beneficial specifically to monitor and assess whether there are changes in their PA and sedentary activity patterns, or assessing different university cohorts as our study only assessed sport and exercise students. Implementing interventions to enhance PA and reduce SB may be important in this population. As we found no associations between sedentary activity, PA and WEBWMS, it may be of interest to assess sedentary activity and PA levels in a more representative sample at stages more psychologically challenging such as examination periods to gain an insight into the relationship between sedentary activity, PA and wellbeing. However, examining the results from this study along with the current literature, an interesting question arises; is examining the period of transition to university life too late to establish the adoption of certain healthy behaviours?

Chapter 4:

A comparison of physical activity and sedentary behaviour components between university students and adult gym-users; and the effect of different exercise training modalities on vascular function, physical activity and sedentary behaviour in adult gym-users.

A comparison of physical activity and sedentary behaviour components between university students and adult gym-users; and the effect of different exercise training modalities on vascular function, physical activity and sedentary behaviour in adult gym-users.

Introduction:

Physical Activity (PA) has been shown to decline (Kwan et al., 2012), and sedentary behaviour (SB) increase with age (Matthews et al., 2008) . The combination of reduced PA and increased SB has the potential to result in decreased health and wellbeing (Lacy et al., 2012; Lee et al., 2012). Therefore, interventions targeted at improving PA or decreasing SB are needed. Whilst PA generally declines with age, there are specific groups or times which may be periods of transition in which behaviours specifically change (McNaughton et al., 2012). University is a time when unhealthy behaviour changes occur, Rouse and Biddle (2010) highlighted that university students spend eight hours per day in sedentary pursuits including: sitting and socialising, watching television and studying. Participants in study 1 spent an average of twelve hours per day sedentary however, they were also active enough to meet current PA guidelines. Excessive participation in sedentary activities has been associated with an increased risk of obesity, independent of PA (Owen et al., 2010). Overall it is evident that levels of SB are high in students attending university (Peterson et al., 2018).

Conversely, adults may choose to attend gyms and undertake structured exercise training, which may influence PA and SB levels. Exercise is a subcomponent of physical activity (PA) whereby planned, structured, and repetitive bodily movements are performed to improve or maintain physical fitness (Howley, 2001). Structured, regular exercise is a key way to improve PA and provide numerous health benefits specifically for cardiovascular parameters and it has therefore been recommended that individuals adhere to exercise training (Swift et al., 2014). Given the evidence from the literature, a comparison between unique adult populations may provide an insight into potential differences in their habitual PA behaviours.

A large body of epidemiological data provide evidence that high levels of PA are associated with reduced risk of many adverse health outcomes including; type 2 diabetes, cardiovascular disease (CVD) and all-cause mortality and others reported that television watching, riding in a car and combined sedentary behaviour (SB) were significantly associated with risk of CVD mortality (Bansil et al., 2011). Moreover, epidemiologic and physiological research has established novel health consequences of prolonged sitting, independent of those attributable to lack of PA including; adverse metabolic and vascular health outcomes (Dunstan et al., 2010). Therefore, both PA and SB may play important and independent roles on cardiovascular health.

Atherosclerosis (Ross, 1999) is a process by which the arteries stiffen and begin to develop plaques, this development and potential rupture of plaques underlies most CVD. The atherosclerotic process begins in the early decades of life with some cases of endothelial dysfunction (an early stage in the development of atherosclerosis) evident even in children with increased risk factors (Celermajer et al., 1992). Heart disease and stroke are the major causes of death in the adult population, with disease of the conduit arteries and dysfunction of resistance arteries associated with hypertension acting as the underlying cause (Green et al., 2011b). Exercise decreases cardiovascular risk (Thijssen et al., 2011), specifically aerobic activities such as, walking, jogging, and cycling which are associated with improved cardiorespiratory fitness (Green et al., 2011b) and have been predominantly recommended for reducing the risk of CVD and improving vascular function (Cornelissen et al., 2011). However, the benefits of resistance activity and training on metabolic health have started to become more apparent within the literature, highlighting the underappreciated aspect of resistance training (Cornelissen et al., 2011). Whilst associations between PA and CV health have been well established, there is less data examining the role of different modes of exercise training on PA and SB levels. It is unknown if participating in specific modes of exercise training can have a strong impact on PA behaviour. Given the growing prevalence of individuals undertaking strength-based training (Dawson, 2015), sometimes in the absence of any endurance training, further information is needed on this relationship. Moreover, there is some evidence that the different modes of exercise training have distinct effects on vascular adaptations with endurance exercise resulting in arterial wall restructuring and resistance exercise impacting on arterial compliance (Green et al., 2011b).

Therefore the aims of this study are 1) components of PA will be compared between university students (study 1) and healthy, adult gym-users 2) investigate the impact of different types of training, endurance-based and resistance-based, on components of PA and vascular function.

Hypothesis

It is hypothesised that the regular adult gym-users will have higher levels of the PA components and lower SB levels compared to university students. It is also hypothesised that endurance-trained individuals will display higher levels of components of PA compared to resistance trained individuals. The endurance-trained individuals will have better vascular function in comparison to resistance-trained individuals.

Methods:

Study design: This is a cross-sectional study. The comparison between participants for study 1 and 2 uses retrospective data collected in study 1 alongside new data collected for study 2.

Participants (study 2): After gaining ethical approvals from the Research Ethics Committee of Liverpool John Moores University (LJMU) and informed consent, sixteen healthy, non-university, adult gym-users (18+ and <50 years old) were recruited for this study. Two groups were recruited, one group consisted of resistance trained participants (N=8) and one group of aerobically trained participants (N=8). Participants were allocated into each training group by being asked which style of training they take part in, endurance or resistance training, when they come into the gym. When they had provided a response, they were allocated into either an endurance or resistance trained group. Participants were required to attend the Underground Training Station (UTS), a performance-based gym located on the Wirral. To be eligible to take part in this study they must have been aged 18-50 years old, no known history of cardiovascular disease including; angina, dysthymia, congestive heart failure, stenosis, valvular disease and hypertrophic cardiomyopathy, no known hypertension or hypocholesteraemia, no known diabetes mellitus, no injuries that prevent them from exercise and a non-smoker.

Protocol: Before providing informed consent, participants were provided with a participant information sheet outlining the testing procedures and specific inclusion criteria that they must have met before being able to participate in the study. To ensure accurate measurement of flow-mediated dilation (FMD), several subject-specific factors had to be taken into consideration: Participants were required to arrive fasted, caffeine free, abstain from alcohol, vitamins, drugs and exercise for >8 hours prior to testing. Upon arrival to the gym, height and weight were measured. The participants then rested in the supine position for 10-15 minutes before having their blood pressure and brachial artery function assessed.

Participants were fitted with one accelerometer, the Actigraph GT39X. The ActiGraph GT39X was worn on each subject's non-dominant wrist; participants wore the accelerometer for a period of seven consecutive days, 24 hours per day.

Testing day: Participants attended UTS and completed the following procedures:

Anthropometric measurements: Participants standing height (Seca 213, Seca, Birmingham, United Kingdom) and body mass (Seca 799, Seca, Birmingham, United Kingdom) was measured using standard techniques. Participants were instructed to relax and lie in the supine position for 10 minutes, following which, their blood pressure and brachial artery endothelial-dependent function (FMD) was assessed.

Flow Mediated Dilation (FMD): FMD was undertaken in line with recent guidelines and represent a nitric oxide-mediated endothelium-dependent vasodilation (Thijssen et al., 2011). A 12-MHz linear array probe attached to a high resolution ultrasound machine (Terason T3000, Terason, Burlington, Massachusetts, USA) was used to measure brachial artery lumen diameter and blood flow velocity. The ultrasound probe was positioned to obtain optimal images of the longitudinal B-mode image of the lumen-arterial wall interface within the brachial artery, with maximal contrast between the lumen and vessel walls. Continuous Doppler velocity assessments were obtained from the middle of the vessel and used to record the blood flow velocity using an insonation angle of <60°.

Each participant was taken through subject preparation whereby they rested in the supine position for 20 minutes in a quiet room. The subjects right arm was extended away from the torso at 80 degrees. Following this a blood pressure cuff was placed distal to the imaged brachial artery on the participants forearm of their right arm. The right brachial artery was imaged in the distal third of the upper arm, at least 2 cm away from the bifurcation. Baseline diameter and blood flow velocity was assessed for 1 minute at rest. The cuff was inflated to

220 mmHg to block arterial inflow. After 5 minutes, the blood pressure cuff was released and changes in arterial diameter and flow velocity were assessed for 3 minutes continuously.

Blood pressure: Blood pressure was assessed using a manual sphygmomanometer (Dinomap, GE Pro 300V2, Tampa, FL) on the left, upper arm, according to manufacturer instructions. This was taken before the start of the FMD test after the 20 minute rest period.

FMD data analysis:

Vascular Measures: Post-test analysis of the artery diameter was performed using custom-designed edge-detection and wall-tracking software, which is largely independent of investigator bias (Thijssen et al., 2011). Settings were recorded and maintained across each participant to establish consistency. The software is written in the icon-based graphical programming language (LabVIEW 7.0) and uses an IMAQ vision tool kit for image handling and analysis routines, with arterial analysis using edge-detection methods. From synchronised diameter and velocity data, blood flow (the product of lumen-cross-sectional area) and Doppler velocity can calculated. FMD (%) was calculated as the percentage change from baseline diameter to automatically determined peak dilation. The time to peak and the shear rate area under the curve (SRauc; the shear rate from cuff deflation to peak dilation) were also determined.

Physical Activity (PA) and Sedentary Behaviour (SB) measures: PA data was obtained using two accelerometer devices. Participants were fitted with an accelerometer, the Actigraph GT39X. The Actigraph GT39X device was worn on each participant's non-dominant wrist to record movement and classify activity as either, light, moderate, or vigorous intensity PA. This device was initialised to record data at 30Hz. Participants were instructed to wear the accelerometer for a period of seven consecutive days, 24 hours. Minimum wear time was set at 10 hours per day, and participants had to provide at least three valid days of data. Non-wear time was estimated in GGIR based on the standard deviation and value range for each axis, which was calculated for 60-minute windows with 15-minute moving increments. If the standard deviation was less than 13 mg or the range was less than 50 mg for at least 2 of the 3 axes this period was classed as non-wear (Rowlands et al., 2016). In this study, the default non-wear setting was used in GGIR whereby invalid data were imputed by the average at similar time points on different days of the week (Rowlands et al., 2016).

Accelerometry data handling and storage:

Accelerometer data was stored using the university software system that is password protected and regularly backed up. ActiGraph wrist data were downloaded using ActiLife v. 6.11.4 (ActiGraph, Pensacola, FL) and saved in raw format as GT3X files. These were subsequently converted to CSV format to facilitate raw data processing. ActiGraph wrist raw data files were then processed in R (http://cran.r-project.org) using the GGIR package (version 1.2-11) using parts 1 and 2. GGIR is an R studio package that processes raw accelerometer data and has been designed for data collected under free-living conditions (van Hees et al., 2014). This process involved the conversion of raw triaxial acceleration values into one omnidirectional measure of acceleration, termed the signal vector magnitude (SVM). SVM was calculated from raw accelerations from the three axes minus 1g which represents the value of gravity (i.e., SVM = $\surd(x^2 + y^2 + z^2) - 1$), after which negative values were rounded to zero. This metric is referred to as the Euclidean norm minus one (EMNO) (van Hees et al., 2013). Wear time was set at 10 hours per day and participants had to provide at least 3 days of valid wear to be included for analysis.

Device specific prediction equations (Hildebrand et al., 2014) were used to identify ENMO cut points for classifying moderate to vigorous PA (MVPA). The Hildebrand cut points were used: 0-45m*g* (Sedentary), 45-100m*g* (LPA), 100-429m*g* (MPA), and 429-8000 m*g* (VPA) This data along with the other quantitative data was statistically analysed and descriptive statistics were reported for each outcome measure using SPSS.

Statistical analysis:

Descriptive statistics for all participant characteristics for population (university students and adult gym-users), gender and mode of training for adult gym-users can be viewed in tables 1, 4 and 5. Independent t-tests were used to compare between participant characteristics for illustrative purposes.

Main analysis

To compare between participants from study 1 and study 2, multivariate analysis of co-variance (MANCOVA) was used to compare PA components between university students and adult gym-users. Two models were completed. For models one and two the dependent variables included were: SB, MPA, VPA and MVPA. For model one gender, age, BMI and wear time were controlled for (table 2). For model two, age was removed as a covariate to examine any age-related differences (table 3).

A MANCOVA model was used to establish any differences between the endurance and resistance trained adult gym users on the variables; BMI, waist circumference, FMD, SB and MVPA (controlled for wear time and sex) (table 6). For all analyses, statistical significance was set at P<0.05. All analyses were cross-sectional and conducted using IBM SPSS Statistics v.23 (IBM, Armonk, NY) and Microsoft Excel 2010 (Microsoft, Redmond, WA).

Results:

Comparison of participant characteristics and PA components between university students and adult gym-users

All participant characteristics (age, stature, body mass, BMI and waist circumference) for the adult gym-users were significantly higher than the university students (see table 1).

Table 1: Participant characteristics of university students and adult gym-users

Measure	Students (n=39)	Gym-users (n=16)	*P* value
Age (yrs)	19.08 ± 1.16	38.38 ± 6.43	<0.001
Stature (m)	1.70 ± 0.08	1.69 ± 0.09	<0.001
Body Mass (kg)	67.22 ± 10.15	79.18 ± 20.24	<0.001
BMI (kg/m^2)	23.13 ± 2.23	27.48 ± 6.22	<0.001
Waist Circumference (cm)	74.55 ± 8.42	84.53 ± 13.95	0.023

For MANCOVA model 1, there were no significant differences between university students (n=39) and adult gym-users (n=16) PA components including; SB, MPA, VPA and MVPA when gender, age, BMI and wear time were controlled for (see table 2).

Table 2: PA components in university students and adult gym-users (MANCOVA) including age as a covariate. Adjusted and actual means, SE and standard deviations (SD) reported.

PA components (min/day)	Students (n=39) actual means ± SD	Students (n=39) adjusted means ± SE	Gym-users (n=16) actual means ± SD	Gym-users (n=16) adjusted means ± SE	*P* value
SB	708.47 ± 72.33	727.17 ± 21.45	732.05 ± 76.23	686.48 ± 47.15	0.534
MPA	112.65 ± 41.33	104.30 ± 11.56	112.21 ± 35.07	132.56 ± 25.41	0.423
VPA	7.42 ± 5.03	9.37 ± 1.40	9.62 ± 6.41	4.87 ± 3.07	0.293
MVPA	120.17 ± 44.77	113.67 ± 12.42	121.84 ± 36.74	137.43 ± 27.30	0.530

For MANCOVA model 2, when age was removed as a covariate, a significant difference in VPA was observed groups in favour of the adult gym-users ($P = 0.010$). There were no significant differences between university students and adult gym-users other PA components including; SB, MPA and MVPA when gender, BMI and wear time were controlled for (see table 3).

Table 3: PA components in university students and adult gym-users (MANCOVA) age removed as a covariate. Adjusted and actual means, SE and standard deviations (SD) reported.

PA components (min/day)	Students (n=39) actual means ± SD	Students (n=39) adjusted means ± SE	Gym-users (n=16) actual means ± SD	Gym-users (n=16) adjusted means ± SE	*P* value
SB	708.47 ± 72.33	713.56 ± 14.24	732.05 ± 76.23	719.65 ± 26.41	0.860
MPA	112.65 ± 41.33	109.58 ± 7.65	112.21 ± 35.07	119.70 ± 14.18	0.586
VPA	7.42 ± 5.03	6.18 ± 1.01	9.62 ± 6.41	12.64 ± 1.86	0.010*
MVPA	120.17 ± 44.77	115.76 ± 8.19	121.84 ± 36.74	132.34 ± 15.19	0.406

Adult gym-users participant characteristics

Sixteen subjects provided accelerometer data and all of these met the inclusion criteria for analysis*,* 6 males and 10 females. Participant characteristics by gender are reported in table 4. There were significant differences for waist circumference ($P = 0.003$) and body mass ($P = 0.006$) and almost significant differences for BMI (P = 0.057) between males and females.

Table 4: Participant characteristics of adult gym-users

Measure	Males (n=6)	Females (n=10)	Independent t-test (*P* =)
Age (years)	39 ± 7	38 ± 7	0.718
Body Mass (kg)	95 ± 13	70 ± 17	0.006*
Stature (m)	1.75 ± 0.11	1.66 ± 0.06	0.109
BMI (kg/m^2)	31.3 ± 5.4	25.2 ± 5.7	0.057
-Overweight (%)	50%	30%	
-Obese (%)	50%	10%	
Waist Circumference (cm)	97 ± 11	77 ± 9	0.003*
% meeting 150 minutes/week	100	100	
MVPA (minutes/day)	109.53 ± 31.00	129.22 ± 39.42	0.288
SB (minutes/day)	758.04±80.10	716.46±73.48	0.325
LPA (minutes/day)	138.15±23.83	141.76±30.55	0.797
MPA (minutes/day)	100.85±32.48	119.03±36.42	0.322
VPA (minutes/day)	8.69±5.30	10.19±7.21	0.640

Participants overweight/obese are displayed as a percentage (%) of BMI for both genders. Significant P values are displayed with an asterisk (*), P <0.05. Subjects were compared using t-tests.

Adult gym-users and training group

The endurance group was significantly older than the resistance group, but there were no differences in any other anthropometric data. There was a significant difference between both groups for vigorous intensity PA (VPA) (P = 0.005) (see table 5).

Table 5: Participant characteristics of adult gym-users either endurance or resistance trained.

Measure	Endurance (n=8)	Resistance (n=8)	Independent t-test (*P* =)
Age (years)	43 ± 6	34 ± 3	0.002*
Body Mass (kg)	79 ± 22	79 ± 20	0.964
Stature (m)	1.69 ± 0.10	1.69 ± 0.09	0.889
BMI (kg/m^2)	27.4 ± 6.0	27.6 ± 6.8	0.936
-Overweight (%)	25%	37.5%	
-Obese (%)	25%	25%	
Waist Circumference (cm)	88 ± 15	81 ± 13	0.398
Males (%)	37.5%	37.5%	
Females (%)	62.5%	62.5%	
% meeting 150 minutes/week	100	100	
MVPA (minutes/day)	120.79 ± 34.25	122.88 ± 41.43	0.914
SB (minutes/day)	748.63±80.22	715.47±73.40	0.403
LPA (minutes/day)	142.01±22.58	138.79±33.12	0.824
MPA (minutes/day)	107.01±32.99	117.41±38.54	0.572
VPA (minutes/day)	13.77±5.77	5.47±3.93	0.005*

Participants overweight/obese are displayed as a percentage (%) of BMI and participants male or female are displayed as a % for both groups. Significant P values are displayed with an asterisk (*), $P<0.05$.

There were no significant differences between individuals who were endurance trained or resistance trained for BMI (P = 0.956), or waist circumference (P = 0.230), FMD (P = 0.885), MVPA (P = 0.904) or SB (P = 0.313) (see table 6).

Table 6: Mean and Standard Error (SE) of PA components between endurance and resistance groups (MANCOVA). Adjusted and actual means, SE and standard deviations (SD) reported.

Measure	Endurance (n=8) actual means ± SD	Endurance (n=8) adjusted means ± SE	Resistance (n=8) actual means ± SD	Resistance (n=8) adjusted means ± SE	*P* value
BMI (kg/m^2)	27.35 ± 6.03	27.40 ± 2.14	27.61 ± 6.83	27.57 ± 2.14	0.956
Waist circumference (cm)	87.63 ± 15.21	87.71 ± 3.51	81.50 ± 12.78	81.42 ± 3.51	0.230
FMD (%)	4.36 ± 4.76	4.31 ± 2.00	4.67 ± 5.77	4.73 ± 2.00	0.885
MVPA (min/day)	120.79 ± 34.25	120.61 ± 13.98	122.88 ± 41.43	123.06 ± 13.98	0.904
SB (min/day)	748. 63 ± 80.22	750.99 ± 25.40	715.47 ± 73.40	713.10 ± 25.40	0.313

Adult gym-users FMD

There were no significant differences in FMD % (P = 0.885) or any other ultrasound-derived values, including artery baseline diameter (Table 7).

Table 7: Participant characteristics of FMD for both endurance and resistance trained groups.

Measure	Endurance (n=8)	Resistance (n=8)	Independent t-test (*P* =)
FMD Change (%)	8.7 ± 1.5	9.3 ± 4.4	0.806
Baseline Diameter (mm)	3.2 ± 0.5	3.7 ± 0.1	0.393
Peak Response (cm)	0.35 ± 0.05	0.40 ± 0.10	0.371
Delta Diameter (mm)	0.2 ± 0.0	0.3 ± 0.0	0.436
Time to Peak (s)	44 ± 12	59 ± 17	0.205
Response SRAUC (AUC) ($s^{-1}10^3$)	18.0 ± 62.6	23.7 ± 95.2	0.365
Systolic BP (mmHg)	126 ± 15	128 ± 17	0.863
Diastolic BP mmHg)	78 ± 9	82 ± 16	0.678

Discussion:

Comparison of university students and adult gym-users

Although there were no significant differences between all PA components, the findings from this study support the hypothesis as adult gym-users displayed higher VPA levels in comparison to the university students. Therefore, in contrast to the literature, the findings from this study demonstrate that age-related declines in PA are not evident in this population. Participants in both studies were all active, with all of them meeting the recommended MVPA guidelines of 150 minutes per week, which could explain the lack of differences between the other PA components (SB, MPA and MVPA). This largely homogenous group may impact on the ability to detect associations between PA and markers of health. The fact that the adult group were gym-users and the university students were 'Sport Science' students means that these groups are not generalisable to equivalent ages in the general population. Both studies consisted of relatively small sample sizes which may have compromised statistical power.

Adult gym-users undertaking either endurance or resistance-based training

This study also investigated PA, SB and vascular health in adult gym-users who regularly took part in either endurance or resistance training type exercise. All of participants in the endurance and resistance trained groups met the recommended PA guidelines and there was no significant difference between either group for MVPA minutes per day achieved. All participants displayed typical FMD values and no significant differences were discovered between the groups for any markers of cardiovascular health.

Exercise training and vascular function

The FMD values present in this study are in line with a normal, healthy population (Thijssen et al., 2009b). FMD is a surrogate marker of CVD and provides an index of NO mediated endothelium-dependent vasodilator function in humans (Green et al., 2004). As endothelial dysfunction is an early atherosclerotic event, assessment of endothelial function can be used to predict future cardiovascular events in later life (Green et al., 2011a). Typically, there is a progressive loss in endothelial function with aging and this is thought to contribute to the increased risk of atherosclerosis and thrombosis (Taddei, 1993). Conversely, exercise training is shown to delay the development of cardiovascular disease, although it is unclear as to which type of PA and exercise training mode (including endurance, resistance training or both) actually reduce the severity of cardiovascular risk factors such as, high blood pressure, metabolic risk factors and obesity (Vanhees et al., 2012). Traditionally, the reduction in cardiovascular risk with exercise training was thought to be related to changes in traditional risk factors such as blood pressure and cholesterol (Green et al., 2008; Tremblay et al., 2010). However, changes in these risk factors do not fully explain the reduced risk for future CVD seen with exercise training (Mora-Rodriguez et al., 2014). There is now an argument that exercise is improving the health of the artery, which explains this 'risk-factor gap' (Green et al., 2008). Exercise-induced increase in blood flow, or more specifically shear stress, stimulates the endothelium to produces nitric oxide (NO). In addition to causing vasodilation, NO helps to maintain the health of the vascular wall, reduces the atherosclerotic process and regulates vasomotor function (Green et al., 2011a; Green et al., 2004) thereby reducing coronary events in those who are exercise trained (Green et al., 2004; Whyte & Laughlin, 2010). More specifically, endurance training increases blood flow, reduces circulating levels of haemostatic and inflammatory variables that may interact with increased sheer stress and ultimately aids the production and release of NO. Given that participants attended the gym on a daily basis, this may explain the lack of endothelial dysfunction or change in artery diameter, as exercise improves and maintains vascular health and function (Green et al., 2004; Green et al., 2008).

Mode of exercise training and vascular function

Green et al. (2011b) undertook a review focused on changes in the vasculature of healthy subjects due to exercise training. These authors' highlighted the physiological adaptations to exercise depend upon the intensity of exercise as well as its modality, duration and frequency. The impact of different types of exercise training is complex (Green et al., 2011b). Endurance based or aerobic type exercise is associated with systemic changes in pulse pressure and heart rate, which generate recurrent changes in haemodynamics and arterial shear stress. These episodic increases in shear stress will result in an upregulation of the NO pathway by stimulating the endothelium to produce NO, which enhances vascular function (Green et al., 2004). Resistance exercise results in different skeletal and cardiac muscle adaptations (Naylor, 2008), which may be partly related to the different haemodynamic signals induced by resistance exercise (Thijssen et al., 2009a). In a study by Spence et al. (2013), twenty-seven healthy men were recruited and randomly allocated into either an endurance or a resistance-training group. These participants completed a six-month exercise intervention consisting of three, one-hour weekly training sessions. The results of their study indicated that resistance training increased resting brachial artery diameter and peak diameter responses to FMD however these upper limb vascular adaptations were not evident for the endurance-trained group. In comparison, endurance training exhibited increased resting and peak diameter response to FMD in the femoral artery after training. However, it is key to note that both modalities could translate to decreased cardiovascular risk. This is in contrast to my findings, where no difference between endurance and resistance trained participants were reported, although only brachial artery function was only assessed in this study. There may be a number of reasons for the lack of difference between the endurance and resistance training participants in my study. It is possible that some participants performed a variety of training sessions including both endurance and resistance training. The limited sample size may also have hindered the achievement of significant results between the endurance and resistance training groups. Previous studies have either used cross-sectional or short-term exercise-training interventions with only a limited number evaluating vascular adaptations for greater than 12 week periods (Spence et al., 2013). Therefore, it may be beneficial to have subjects follow a specific endurance or resistance-training program in the future to help highlight differences in their vascular function following prolonged training of different exercise modes.

Sedentary behaviour and cardiovascular health

As with study one, there was no association between SB and cardiovascular health in the participants in this study. Participants in both the endurance and resistance trained groups spent 12 hours per day in sedentary pursuits, which is in line with the findings from the university students. In contrast, SB has been associated with increased plasma triglyceride levels, decreased levels of high-density lipoprotein (HDL) cholesterol and decreased insulin sensitivity (Tremblay et al., 2010), particularly if no vigorous activity is undertaken. Extreme SB such as bed rest reduces vascular function including decreased reactive hyperaemia in the legs and arms, increased blood pressure, decreases in brachial artery diameter (Hamburg et al., 2007), decreased brachial artery FMD and increased endothelial cell damage (Demiot et al., 2007). Interestingly, this later study demonstrated that that these deleterious changes in vascular function can be prevented by a combination of both aerobic and resistance exercise. The lack of difference in this study may be due to the limited sample size and the relative active nature of all subjects. Participants in this study took part in gym sessions that were either endurance or resistance training based; it was unknown what specific activities they undertook outside of the gym. It is possible that resistance-trained individuals also ran or cycled outside of the gym. If this were the case, they obtained the benefits associated with both modes of exercise training and thus displayed healthy, vascular function.

Waist circumference and vascular function

A small proportion of endurance-trained individuals were classed as being overweight (25%) or obese (25%). In the resistance-trained individuals, 37.5% were overweight and 25% obese. Obesity is associated with increased cardiovascular morbidity and mortality (Department of Health, 2011; Obesity, 2000; Stevens et al., 1998). However, there are some limitations with using BMI, as it does not discriminate fat from lean mass or abdominal from gluteofemoral fat, which can have dissimilar health implications (Snijder et al., 2006). Specifically, abdominal obesity is thought to play a key role in the development of cardiovascular events (Meyers & Gokce, 2007). It has been suggested that measures of central obesity including waist circumference, may be more beneficial to assess body fat distribution, specifically in patients with coronary artery disease (CAD) (Coutinho et al., 2011). Increasing central obesity was associated with higher mortality in patients with CAD through increased cardiovascular events (Coutinho et al., 2011). According to the International Diabetes Federation (2005), visceral adiposity plays a precarious role in the pathophysiology of atherosclerosis. Interestingly, endothelial dysfunction has been proposed as a major causality between abdominal adiposity and the development of atherosclerosis (Meyers & Gokce, 2007). Although there were no significant results for waist circumference in this study, Tremblay et al. (2010) suggested that higher waist circumference values were associated with a higher degree of endothelial dysfunction. Furthermore, increased waist circumference values have been said to be an independent risk factor for the development of hypertension and cardiovascular disease (Yusuf et al., 2005). Again, the lack of association in this study may be due to the small sample size and fitness levels of participants included in this study.

Strengths

To our knowledge, this is the first study to compare PA components in university students and adult gym-users. This is also the first study to investigate PA, SB and cardiovascular health in healthy trained individuals, either taking part in endurance or resistance exercise. Due to the small sample size, accelerometer adherence was extremely high with all sixteen participants providing valid PA and SB data to be included for analysis.

Limitations

A key limitation to this study was that participants were not purely endurance or resistance trained. The endurance participants were recruited from the Fitness Forge (circuit training) section of the gym which consisted of some weight-based equipment. There was no control over what style of training participants performed outside of the gym and no inclusion of a non-exercising group for comparisons. These limitations may possibly explain why no significant differences were evident between the groups. To be included in the study, participants did not have to meet a minimum amount of training sessions however it may have been beneficial to set a minimum amount of sessions either endurance or resistance based in the inclusion criteria. Participants were instructed to remove wrist-worn accelerometer (GT39X) when swimming, showering or taking part in contact sports therefore, we cannot account for activities undertaken during this period of non-wear time. The thresholds used were the best available however, future research could calibrate a set of thresholds for this specific population as these may have affected the activity data by misclassification in activity intensities. Age was not controlled for in the statistical analysis between the training groups (endurance and resistance). Menstruation phase or hormonal contraceptives were not controlled for in this study. Increased endogenous production of oestrogen with progesterone across the menstrual cycle can influence the vasodilatory response therefore FMD measurements in premenopausal women should be performed at the same time of the menstrual cycle (Harris et al., 2010). Although all our participants were of premenopausal age, endothelial dysfunction has been demonstrated during the menopausal transition as women lose the protective effects of oestrogen, which is vital for the vasculature (Moreau et al., 2012). Medication was not controlled for which may have influenced the results as females may have been taking contraceptive pills. Isotemporal substitution could not be used as a method of analysis for this study as the sample size was too small when analysing both training groups (endurance and resistance training groups) and as it does not allow for the comparison of groups, it could not be used to analyse PA components of university students and adult gym-users. This was a very small sample size and the participants included were of a healthy population, engaging in regular PA with no reported adverse health conditions, which is likely why there were no significant effects observed.

Conclusion

There were no significant differences between university sport science students and healthy adult gym-users PA components including; SB, MPA, VPA and MVPA when gender, age, BMI and wear time were controlled for. All endurance and resistance trained individuals met the recommended MVPA guidelines and no significant differences were discovered for mode of training on PA components, markers of health (BMI and WC) and vascular function. However, given our knowledge on the different adaptations on vascular function from either endurance or resistance training, we propose that with a larger sample size and different ages, greater insights into the influence of different modes of exercise training on PA and vascular function will be elucidated. As this study used a trained population, future research could investigate non-exercising individuals and randomly allocate them into endurance or resistance training groups and follow them for a prolonged training period. This study provides support for the importance of maintaining exercise across the adult lifespan.

Chapter 5:

General Discussion

General Discussion

Aims of this thesis

The overall aim of the thesis was to investigate PA and SB behaviour patterns during adulthood and to examine the role of university life or regular gym use on these patterns. Study one was focussed on markers of health (BMI and WC) and wellbeing (WEMWBS) and Study two was focussed on the same markers of health (BMI and WC) and in addition a marker of vascular function (FMD). A comparison between individuals who typically did aerobic based training compared to predominantly strength-based training was also investigated. The components of PA between university students (study 1) and adult gym-users (study 2) were investigated to determine if university versus regular gym use influenced PA and SB.

Main findings from this thesis

The findings from study 1 demonstrated no significant associations of PA and SB on BMI waist circumference and wellbeing in a young, healthy and active population. When a comparison was made between the PA components of the university students and adult-gym users in the second study, adult gym-users displayed higher VPA levels however there were no differences between the other PA components, SB, MPA and MVPA. All participants in both studies could be classed as active as they all met the recommended 150 minutes MVPA guidelines (Department of Health, 2011). Contrary to the hypothesis, there was no difference in most PA components (SB and MVPA) and markers of health (BMI, waist circumference and FMD) between endurance and resistance trained adult gym-users. However, when only PA data was compared between the two groups, the endurance group displayed higher VPA levels when compared with the resistance group. These largely homogenous groups may impact on the ability to detect associations or differences between PA and markers of health. The fact that the university students were 'Sport Science' students and the adult group were gym-users, this means that these groups are not generalisable to equivalent ages in the general population. Both studies consisted of relatively small sample sizes therefore, this may have compromised statistical power.

PA behaviour, health and wellbeing in university students

In the sample of university students, all met the recommended 150 minutes MVPA guidelines (Department of Health, 2011) however this cohort still displayed high levels of SB (12 hours per day). As demonstrated by the literature, specific transitional periods during adulthood can influence the behaviour patterns of unique populations (McNaughton et al., 2012). More specifically, large proportions of adolescents (92%) who are transitioning from childhood to adulthood were classified as not meeting the current PA guidelines (Troiano et al., 2008). In light of this reduction in PA in recent decades, it has been suggested that the current generation may have a shorter life expectancy than that of their parents (AHA, 2011). There is only a small body of research that has examined PA in the university population. Overall, PA levels of university students have been measured subjectively and inconsistently using self-reported methods making it difficult to draw comparisons across samples of this specific population (Keating et al., 2005). Nonetheless, the findings from this thesis are in agreement with a similar study conducted in university students (Peterson et al., 2018). These authors demonstrated the uniqueness of this specific population whereby their levels of both MVPA and SB were high, suggesting an active but sedentary lifestyle.

The findings from study 1 demonstrated no significant associations of SB on BMI and waist circumference in a young, healthy and relatively active population. Again, this is contrary to what has been found in larger population studies whereby replacing SB with MVPA in adults, MVPA was associated with favourable effects in BMI (Hamer et al., 2014). Buman et al. (2014) highlighted that in adults, beneficial associations were evident for waist circumference when sedentary time was reallocated as MVPA. Time spent in SB has also been positively associated with measures of waist circumference in a university population (Petersen et al., 2018). In this thesis when markers of health were investigated using isotemporal substitution, there were no significant effects of substituting SB, LPA or MVPA on these measures including; BMI, WC and wellbeing (WEMWBS) in either university students. However, there are still very few studies that have examined PA in university students using objective measures and associated it with markers of health and wellbeing. As a consequence of the focus in the literature being targeted towards young people and sedentary screen time, it is still unclear as to what approach is required to change SB in adults/transition from adolescence to adulthood (Biddle & Asare, 2011). Evidently, high levels of SB (independent to PA) increases the risks of developing numerous chronic conditions and causes early mortality in men and women (Ekelund et al., 2016). Future work with a larger sample size, in different types of university students and at different points of their academic career, is needed to determine if the effect of SB on health is also apparent in this population and to gain a more representative overview of students' physical activity behaviours.

In addition to markers of health, study 1 also presented self-reported markers of wellbeing. WEMWBS, is a fourteen-item scale survey that assess wellbeing (Tennant et al., 2007). In contrast to the hypothesis, there was no significant relationship between PA and WEMWBS. Nonetheless, throughout the last decade, mental illness has become a serious health issue across the lifespan (Biddle & Asare, 2011). By 2020, it is expected to account for 15% of the global burden of disease, making it a leading disease burden within our population (Biddle & Mutrie, 2008). As demonstrated by the literature, PA positively effects a variety of aspects of mental illness. This may explain the findings from the wellbeing survey (WEMWBS) in the sample of university students, as they were all well and active individuals especially being 'Sport and Exercise Science' students, a homogenous group not representative of the wider student population. Differences in levels of wellbeing factors including distress, have been evident over the course of the year university year (Bewick et al., 2010). Therefore, further work should investigate wellbeing at different time points throughout the academic year as this data collection was during the second semester of the students first year where stress may not be as high as seen in exam periods or in later academic years. Bewick et al. (2010) highlighted that distress levels were highest during semester one of students' first year but with significant reductions in psychological distress from semester one to semester two.

PA behaviour and vascular function in endurance and resistance trained adults

In a sample of adult gym-users, there were no significant differences demonstrated by either endurance-based or resistance-based training groups on markers of health including; BMI, WC, vascular function (FMD) and activity data including SB and MVPA. This may be related to the small numbers assessed or it may be that both modes of exercise training are beneficial on PA and health outcomes. Further work is needed to see if PA patterns and associated health outcomes change throughout the adult lifespan and if different factors, such as changing lifestyle through work/university and different modes of exercise training, can influence PA and associated health outcomes. The recommended 150 minutes/week MVPA guidelines were met by both training groups. However, the endurance-based training group displayed significantly higher levels of VPA in comparison to the resistance-based training group. Currently, there is limited evidence in the literature to support these findings possibly due to the lesser-researched aspect of resistance training (Cornelissen et al., 2011). Further work is therefore needed to fully understand this relationship. Unfortunately, numbers were too small to run the isotemporal substitution analysis in the second study investigating adult gym-users, but given that they were all active, it may have reflected what was found in the active university students.

Exercise training is a targetable method to increase daily PA and achieve the PA guidelines (Swift et al., 2014). Physical inactivity (not meeting guidelines) is associated with the world's major non-communicable diseases (Ding et al., 2016) with strong evidence to suggest many health benefits for adults who engage in sufficient PA (Kohl et al., 2012) including, reduced risk of all-cause mortality, coronary heart disease, high blood pressure, stroke, metabolic syndrome, cancer, depression and falling, especially in the elderly (Lee et al., 2012). Cardiometabolic biomarkers such as obesity and high cholesterol levels are strong predictors of CVD (Heart & Stroke Foundation of Canada, 2012). In study 1, forty percent of males were classed as being overweight. However, this specific sample was comprised of "Sport and Exercise students" and perhaps spending large amounts of time spent in the gym or playing sport, which would build lean mass. The issues around using BMI as a measure of weight status were outlined in the earlier studies; more specifically some individuals may have more lean mass than fat mass and were consequently misclassified as being overweight. A small proportion of the participants of study 2 were classed as either overweight or obese. These participants were all gym-users, engaging in a variety of weight-based exercise that has been demonstrated to enhance muscle mass (Howley, 2001). Future work specifically targeting markers of health/obesity should therefore use other 'gold standard' measures such as a DXA scanner to measure percentage body fat (Gaele et al., 2012) to alleviate the inaccuracies of using BMI as a measurement tool.

Currently, there is limited evidence on the impact of different modes of training and the impact these have on habitual PA and SB levels within the adult population. The use of different modes of exercise training is becoming more prevalent, particularly with resistance (strength training) gaining popularity among the general public in recent years such as weightlifting and cross-fit which has been branded as 'the sport of fitness' (Dawson, 2015). Participants in study 2 were not purely endurance or resistance trained. The endurance participants were recruited from the Fitness Forge (circuit training) section of the gym which consisted of some weight-based equipment. There was no control over what style of training participants performed outside of the gym therefore it is quite possible they may have been engaging in a combination of both forms of training. There was also no inclusion of a non-exercising group for comparisons. This may provide explanation as to why there were limited differences displayed by either group on PA and SB levels, BMI, waist circumference and FMD. Whilst no significant findings were observed from study 2 for MVPA and SB levels of the participants, a possible explanation for this would be the sample size used as it was relatively small, making it difficult to draw any meaningful conclusions. Although participants in the endurance-based training group displayed significantly higher VPA levels than those in the resistance-based training group, perhaps a larger sample size would provide more significant observations, which would add novel findings to the exercise training modality literature. Given that there are no other studies comparing PA behaviour in endurance versus resistance-trained adults, further work is needed to establish if different modalities of training effect PA behaviours.

The participants of study 2 demonstrated no difference in vascular function or artery baseline diameter between endurance and resistance trained individuals. Unfortunately, the FMD data could not be included in the isotemporal analysis due to small sample size. The lack of difference between training groups and 'normal' FMD values in this group are most likely due to the fact that they were active, weekly gym-users. Exercise increases blood flow which increases shear stress. This shear stress stimulates the endothelium to produce nitric oxide, which reduces the atherosclerotic process. This increase in NO production, can also result in an improvement in FMD, which is ultimately superseded by an increase in resting artery diameter (Tinken et al., 2008). Overall, this process enhances vascular function thereby reducing the occurrence of cardiovascular disease (CVD) (Green et al., 2004). In contrast to the findings in this thesis, the noticeably different effects of the adaptations to mode of exercise is starting to become more apparent (Naylor, 2008; Thijssen et al., 2009a). This may be related to differences in blood flow and shear rate patterns with these two different modalities of training (Thijssen et al., 2009a), which elicit distinct physiological adaptations (Green et al., 2005). In a 6 months training study, Spence et al. (2013) examined vascular function after undertaking either endurance or resistance training. Importantly, they reported that prolonged periods of training in one modality of exercise to the other is essential to demonstrate the effects of these different modes of training as shorter durations may not be sufficient. These authors concluded that even though the different modes of exercise result in different adaptations. Resistance training increased resting brachial artery diameter and peak diameter responses to FMD however these upper limb vascular adaptations were not evident for the endurance-trained group. In comparison, endurance training exhibited increased resting and peak diameter response to FMD in the femoral artery after training. However, whether individuals engaged in endurance or resistance training, the impact that each mode had on arterial size, function and wall thickness ultimately resulted in a decreased CV risk, albeit it via different mechanisms (Spence et al., 2013). It is important to note though that, similar to this study, there was no difference in the vascular measure (FMD) or resting baseline artery diameter in these adult gym-users. This may suggest no impact on either function (FMD) or structure remodelling (increasing in artery size with exercise training). However, it should be noted that resting diameter is under the influence of factors that can change artery tone and therefore may be limited in its use as a mark for artery restructuring. This highlights the need to look at multiple markers of vascular function and health including measures of vascular structure such as intima-media thickness (IMT) and peak dilation as a surrogate for artery restructuring and potential disease progression.

Future research

Overall, the literature highlights the benefits of PA and reduced SB impact on a wide range of physiological functions associated with improved quality of life and reduced occurrence on non-communicable diseases (Lee et al., 2012). Although the university students in study 1 were active, their level of SB was also extremely high (12 hours per day). Therefore, it may be beneficial to implement interventions that target SB to provide the most influential effects for this unique population to maximise physical wellness. It may have been beneficial to collect baseline data in study 1 when participants enrolled on their degree programme and investigated this data with a follow-up period at the end of their degree. This would allow for a larger data set which may provide more evident associations between PA, SB, BMI, waist circumference and wellbeing.

To explore the relationship between endurance and resistance training, markers of health including vascular function and PA components further, larger sample sizes are required and implementing interventions that incorporate both modalities of training. This would help to add to a novel area of literature that at the moment appears sparse. Study 2 could have incorporated university students who were endurance or resistance-trained and investigated the impact these modes of training had on PA components as well as being able to make a comparison with endurance or resistance trained adult, gym-users. Unfortunately, study 2 did not include a measure of wellbeing due to the time constraints of data collection. This may be a useful addition to future research in this area as the literature demonstrates that varying PA intensities are influenced by a number of factors including gender which impact mental health. Nonetheless, PA positively influences mental health (Asztalos et al., 2010). It would be hypothesised that similar findings to study 1 would be discovered in larger sample size of active individuals.

The analysis in this thesis of raw accelerometer data is a relatively novel method to assess PA and SB patterns (Fairclough et al., 2017). Aside to isotemporal substitution, a possible analysis that could be used in future research is compositional data analysis. This technique examines co-dependent daily behaviours captured across 24 hour movement data and it has been suggested to better understand the impact of different movement behaviours on indicators of health including adiposity and cardiorespiratory fitness. As demonstrated in this thesis, the isotemporal substitution technique allows for the reallocation of one activity intensity on another. This technique will help to inform researchers and health practitioners of the health implications of reallocating time to different PA intensities (SB, LPA, and MVPA).

Conclusion

To achieve the overall aim of this thesis two specific populations were investigated, university students and adult gym-users. These unique populations also allowed for the examination of psychological wellbeing and PA during university life, a comparison of PA components between the two populations (university students and adult gym-users) and the role of different exercise training modes and regular gym use on vascular function alongside PA and SB patterns.

In study 1, it was hypothesised that the reallocation of time from sedentary activity to LPA and MVPA would be favourably associated with BMI, WC and wellbeing. In contrast to this, the findings from study 1 demonstrated no associations between, PA, SB and markers of health including BMI, waist circumference and wellbeing in university students. However, all participants met the recommended 150 minutes MVPA guidelines although demonstrated high levels of sedentary behaviour (12 hours per day).

In study 2, it was hypothesised that the healthy, adult gym-users would have higher levels of PA compared to the university students. When age was removed as a covariate, adult gym-users displayed significantly higher VPA levels in comparison to the university students. This finding highlights that age-related declines were not evident across the adult population in contrary to the literature. The finding also provides evidence that regardless of mode of exercise training, exercise training in general results in greater VPA levels. A secondary hypothesis was that endurance-trained participants would display higher levels of PA compared to resistance-trained participants. In agreement with our second hypothesis, when activity data was compared between each training group, endurance-trained participants displayed significantly higher VPA levels in comparison to resistance-trained participants. There were no evident relationships between PA, SB, and mode of exercise consisting of endurance and resistance training and markers of health including BMI, waist circumference and vascular function (FMD) in healthy, adult gym-users.

The main limitations of this study were the small sample sizes, the homogenous groups assessed, the lack of consistent assessments across all studies and the inability to control the specific training modes outside of the gym in study 2. Further work is required to determine the impact of undertaking different modes of exercise training on habitual PA and associated markers of health, specifically vascular function and wellbeing. In addition, larger and more varied adult populations from young adults to the elderly are needed to determine various factors that influence PA and SB behaviours with different age groups. This thesis highlighted the benefits of using subjective and novel measurement and analysis techniques. Ultimately, further work is needed to determine the role of PA and SB behaviours on different measurements of health and wellbeing in the general population.

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